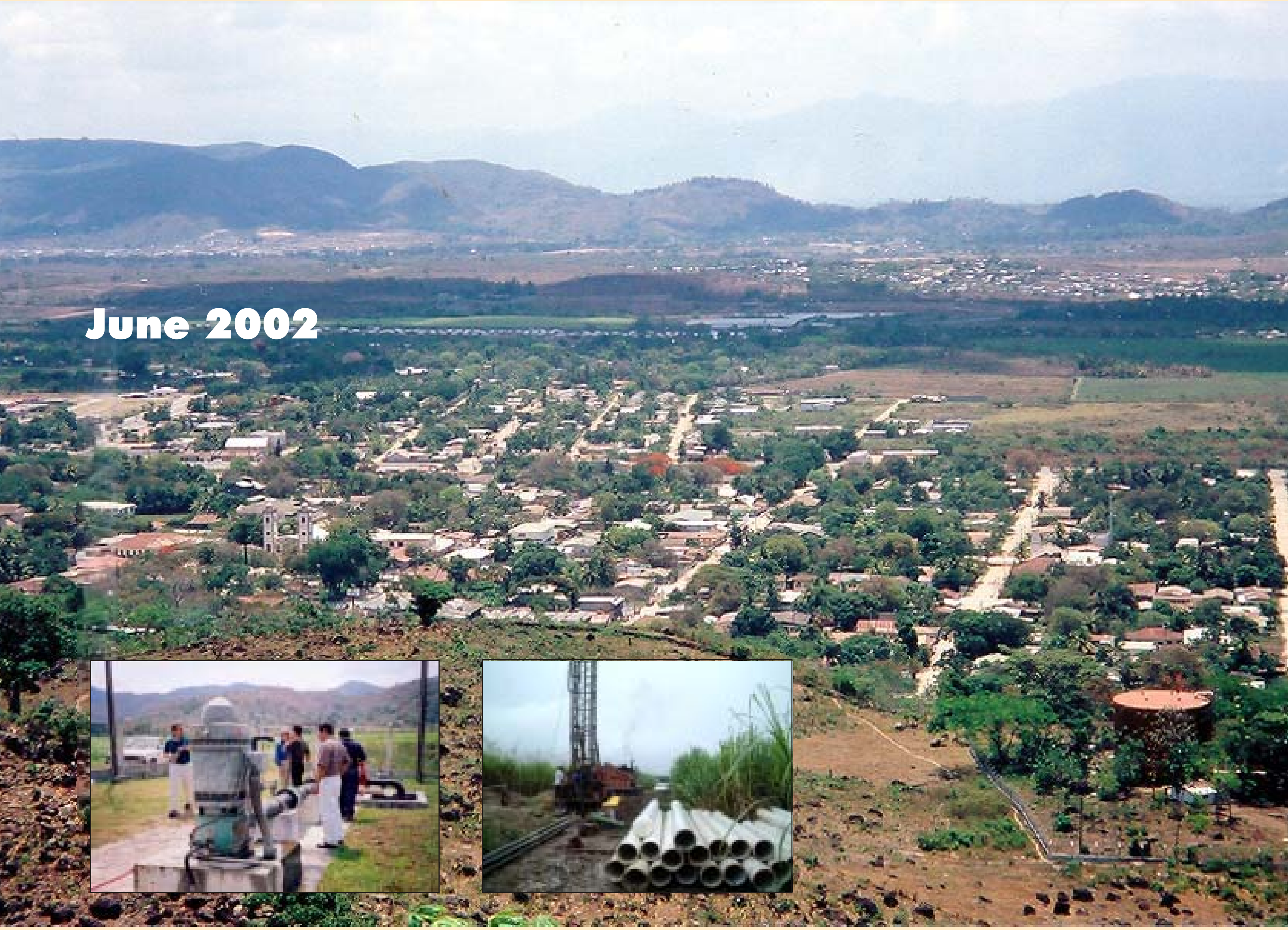
GROUNDWATER RESOURCES MONITORING REPORT AND MANAGEMENT PLAN

Villanueva, Republic of Honduras, C. A.



June 2002

Prepared for:

United States Agency for International Development

USAID

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BROWN AND CALDWELL

July 25, 2002

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Avenida La Paz, Post Office Box 3453
Tegucigalpa, M.D.C., Honduras

Subject: Groundwater Resources Monitoring Report and Management Plan, Villanueva, Honduras, Contract No. 522-C-00-01-00287-00

Dear Ing. Cruz:

In accordance with the above referenced contract, Brown and Caldwell is pleased to forward two copies of the English version of the Groundwater Resources Monitoring Report and Management Plan for Villanueva, Honduras. The Spanish language version of this report is being submitted separately. Each report includes the electronic file of the report and the Water Resources Management System on two separate compact disks.

The submittal of this report and the reports for Limón de la Cerca, Choloma, Utila, and La Lima complete our work under this contract.

We appreciate the opportunity to have been of service to USAID. If you have any questions, please do not hesitate to give me a call at (925) 210-2278.

Sincerely,

BROWN AND CALDWELL

Jeffrey C. Nelson

Jeff Nelson, P.E.
Project Director

JN:PS:ap
Enclosure

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bgs	below ground surface
ft	feet
GIS	geographic information system
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
in	inch
km	kilometer
lpcd	liters per capita per day
lps	liters per second
m	meter
mg/L	milligrams per liter
mgd	million gallons per day
mi	mile
mld	million liters per day
mm	millimeter
TDS	total dissolved solids
USAID	United States Agency for International Development
VOC	volatile organic chemicals
WHO	World Health Organization
WRMS	Water Resources Management System
ZIP	zoned industrial park

GLOSSARY OF TERMS

Alluvial: Pertaining to or composed of alluvium or deposited by a stream or running water.

Alluvium: A general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope.

Aquifer: A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs.

Aquifer Test: A test involving the withdrawal of measured quantities of water from or addition of water to, a well and the measurement of resulting changes in head in the aquifer both during and after the period of discharge or addition.

Fault: A fracture in the continuity of a rock formation caused by a shifting or dislodging of the earth's crust, in which adjacent surfaces are displaced relative to one another and parallel to the plane of fracture.

Fluvial: Of or pertaining to a river; produced by or found in a river.

Fracture Trace: A natural linear features less than 1.6 kilometers (1 mile) long that can be identified by aerial photographs.

Graben: A portion of the Earth's crust, bounded on at least two sides by faults that has dropped downward in relation to adjacent portions.

Groundwater: The body of water that is retained in the saturated zone that tends to move by hydraulic gradient to lower levels.

Irrigation: Application of water to the land to meet the growth needs of plants.

Karst: An area of limestone terrain characterized by sinks, ravines, and underground streams.

Lithology: The study of rocks; primarily mineral composition.

Normal Faults: When the fault plane is so inclined that the mass on its upper side has moved up relatively.

Specific Yield: The ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity to the volume of that mass. This ratio is states as a percentage.

Strike-slip Faults: The component of slip on a fault parallel with the linear extension or strike of the fault.

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EXECUTIVE SUMMARY
Groundwater Resources Monitoring Report and Management Plan
Villanueva, Honduras
June 2002

The United States Agency for International Development (USAID) contracted Brown and Caldwell to perform groundwater monitoring studies for the Island of Utila and the urban areas of the municipalities of Villanueva, Choloma, La Lima, and resettlement the community of Limón de la Cerca, near Choluteca. This Groundwater Resources Monitoring Report and Management Plan (Report) presents the results of the groundwater monitoring study and includes a groundwater resource management plan to help ensure the sustainable management of the groundwater resources for Villanueva, Honduras in the northwestern part of the country. Villanueava lies within the Caribbean low lands, which have a tropical wet climate with an annual precipitation of 2,400 millimeters (94 inches). Villanueva is situated in the western portion of the Sula Valley. The Ulua River is located 5 kilometers (km) (3 miles (mi)) south of Villanueva.

Background

The municipality of Villanueva is located approximately 33 km (21 mi) south of the City of San Pedro Sula, Cortés, Honduras in the northwestern part of the country. Villanueva lies within the Caribbean low lands, which have a tropical wet climate with an annual precipitation of 1,800 millimeters (mm) (70 inches (in)). Villanueva is situated in the western portion of the Sula Valley. The Ulua River is located 5 km (3 mi) south of Villanueva.

Description of Existing Water System and Water Demands

The water system is owned and operated by the municipality of Villanueva. Villanueva relies almost entirely on groundwater for its water supply with a small portion of the supply coming from two spring sources. Sixteen municipal wells provide the water supply for Villanueva with a combined capacity of 193 liters per second (lps) (2,662 gallons per minute (gpm)). Three of the wells are located within a sugar cane plantation south of Villanueva and are the primary sources of water for the municipality. In addition, seven private wells have been identified that are currently operating in Villanueva. These wells do not provide water to the municipal distribution system.

The Villanueva distribution system consists primarily of 3-in to 6-in diameter polyvinyl chloride pipeline and has two pressure zones. The majority of the municipality is served by the lower pressure zone while the upper pressure zone serves a small area in the western portion of Villanueva. There are currently nine storage tanks with a combined storage capacity of more than 2,138,000 liters (564,800 gallons).

In 1998, Villanueva had a population of 25,057. Since published population projections prepared by others have not been identified, the future population has been projected as a part of this study. The population annual growth rate assumed for 2000 through 2010 is based on the growth rate of the developed land area occurring from 1981 to 2000, which was nine percent per year. This study assumes that the growth rate for Villanueva will decrease following the year 2010 to be equivalent to that of the nearby city of San Pedro Sula, which is 5.48 percent per year. The population is expected to reach 100,399 by 2020.

Groundwater use is not precisely known due to a lack of water meters. The current average annual municipal water production is estimated to be approximately 11 million liters per day (mld) (3.0 million gallons per day (mgd)). The per capita water production, including system losses, is assumed to be 341 liters per capita per day (90 gallons per capita per day). Annual municipal water demands are expected to increase to 34.1 mld (9.0 mgd) by the year 2020. Maximum day water demand is estimated to be 1.2 times the average annual day. Therefore, maximum day demand is estimated to increase from 13.7 mld to 40.9 mld (3.6 to 10.8 mgd). If well pumping is limited to a maximum of 20 hours per day, there is no current well supply deficit during the maximum demand day. By 2020, an additional well capacity of 400 lps (6,338 gpm) will be required.

Groundwater Resources Evaluation

The groundwater resources evaluation consisted of the development of a conceptual hydrogeologic model, field investigations, the development of a numeric groundwater model, and the identification of potential contamination sources to groundwater.

The conceptual model for Villanueva was developed based on the understanding that the upland areas surrounding the Villanueva Valley serve as the major surface and groundwater recharge areas for the buried alluvial materials. Groundwater production occurs from the alluvial deposits. Precipitation recharge to the western and eastern highland flows towards the valley and ultimately discharges to the Ulua River.

The conceptual groundwater budget indicates that the basin is approximately in balance. Approximately 271 lps (4,300 gpm) enters the Villanueva Valley aquifers through mountain front recharge and approximately 126 lps (2,000 gpm) flows to the Ulua River. Total existing groundwater pumping is estimated to be 158 lps (2,500 gpm).

Five test wells were installed as part of the field investigation to depths in the 104 m to 207 m (340 ft to 680 ft) range. Aquifer pump tests were performed on selected wells. The results indicate that the best groundwater yields are in the area south of Villanueva. Laterally extensive sand and gravel deposits are present as discontinuous beds and lenses. The thickness and lateral extent of the sands and gravels are greater along the western and southern portions of the valley.

Groundwater samples were collected from the test wells and several of the existing wells. The groundwater quality is generally acceptable, with several exceptions. Several wells have a presence of total and fecal coliform. The test well installed in the northeastern portion of Villanueva and an existing well in the same general area (BCVI-2 and Guadalupe Lopez) have arsenic that slightly exceed the drinking water standard. One existing well has iron over the customer complaint level.

Two predictive model simulations were performed to evaluate the potential effects of increasing groundwater production to year 2020 requirements. Future wells were located to the north of Villanueva for the first simulation. The simulation results indicate that the aquifer drawdown in the vicinity of the wells would be approximately 12 m at the end of 20 years. For the second simulation, future wells were located south of Villanueva. The results indicate that the aquifer drawdown would be approximately 5 m in the vicinity of the wells.

There are several potential sources of contamination to the shallow, fresh water aquifer in Villanueva. These sources include cattle grazing, agricultural activities, industrial discharge, and private wastewater disposal facilities.

Results of the groundwater resource evaluation investigation indicate that the portion of the Villanueva valley with the most potential for future groundwater production and the best water quality is located, generally, south of the municipal center, in the sugar cane fields. The subsurface sediments in this area demonstrated the highest transmissivities and the production capacities of the existing wells in this area exceed that of wells located in other areas.

Water Resources Management System

The Water Resources Management System developed for this project is a desktop computer application developed to store, manage, and analyze groundwater technical information gathered for this project plus data that the municipality will collect in the future. The application is a management tool that can be used by the municipality and other decision-makers to sustainably manage Villanueva's groundwater resources. The system is composed of both a data management system and a geographic information system linked together as one application.

Recommended Groundwater Resources Management Plan

Figure ES-1 presents a groundwater resources planning map. Figure ES-2 depicts a geologic cross-section. The following recommendations are made regarding the management of Villanueva's groundwater resources:

1. As water demands increase, install additional wells in the southern portion of Villanueva. Approximately 8 new wells will be needed by the year 2020, assuming an average well pumping capacity of 47 lps (750 gpm). These new wells will be required approximately every two years. Obtain sites (30 m by 30 m (100 ft by 100 ft)) for these future well sites. New wells should be constructed to include disinfection equipment and a 15 m (50 ft) well seal to address bacteriological contamination. The new wells should utilize water lubed vertical turbine pumps and have a water meter. Convert test wells BCVI-5 to a production well by installing a pump and connecting pipeline.

2. Conduct a regular groundwater monitoring program consisting of monitoring groundwater levels, groundwater useage, and water quality in selected wells. Fifteen wells are suggested for the initial monitoring program. Conduct monitoring quarterly or every three months.

Utilize the database, known as the "Water Resources Management System", to store and analyze the collected data. Conduct a groundwater resources evaluation every 10 to 15 years.

3. Work with other municipalities to help form a regional groundwater management agency. The purpose of this agency would be to help address technical and management issues regarding the groundwater resources.

4. Establish a wellhead protection program to reduce the chance of groundwater contamination impacting water supply wells.

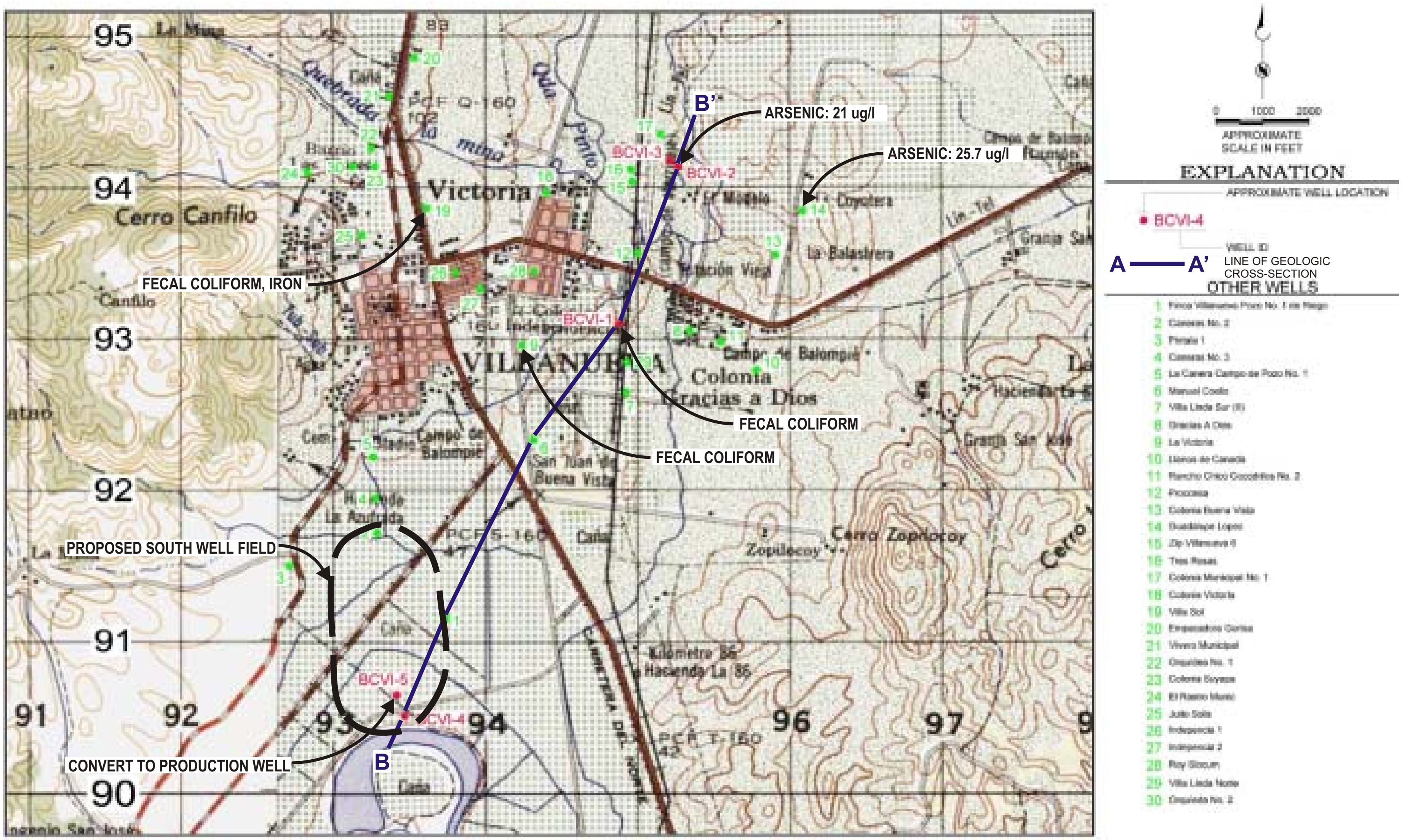
5. Ensure a functioning water utility that is financially self-sufficient by continuing to:
   a. maintain and update the customer inventory;
   b. update the financial plan and charge customers for water useage to ensure that water utility revenues are sufficient to pay for costs;
   c. have trained staff that is familiar with operating a municipal water system; and
   d. investigate potential funding sources for grants and loans.

6. Reduce the number of wells that will be needed in the future by promoting water conservation and reducing leaks from the water distribution system. The first step is to conduct a study to define the amount of water loss and recommend the best areas for leak repair and/or water main replacement.

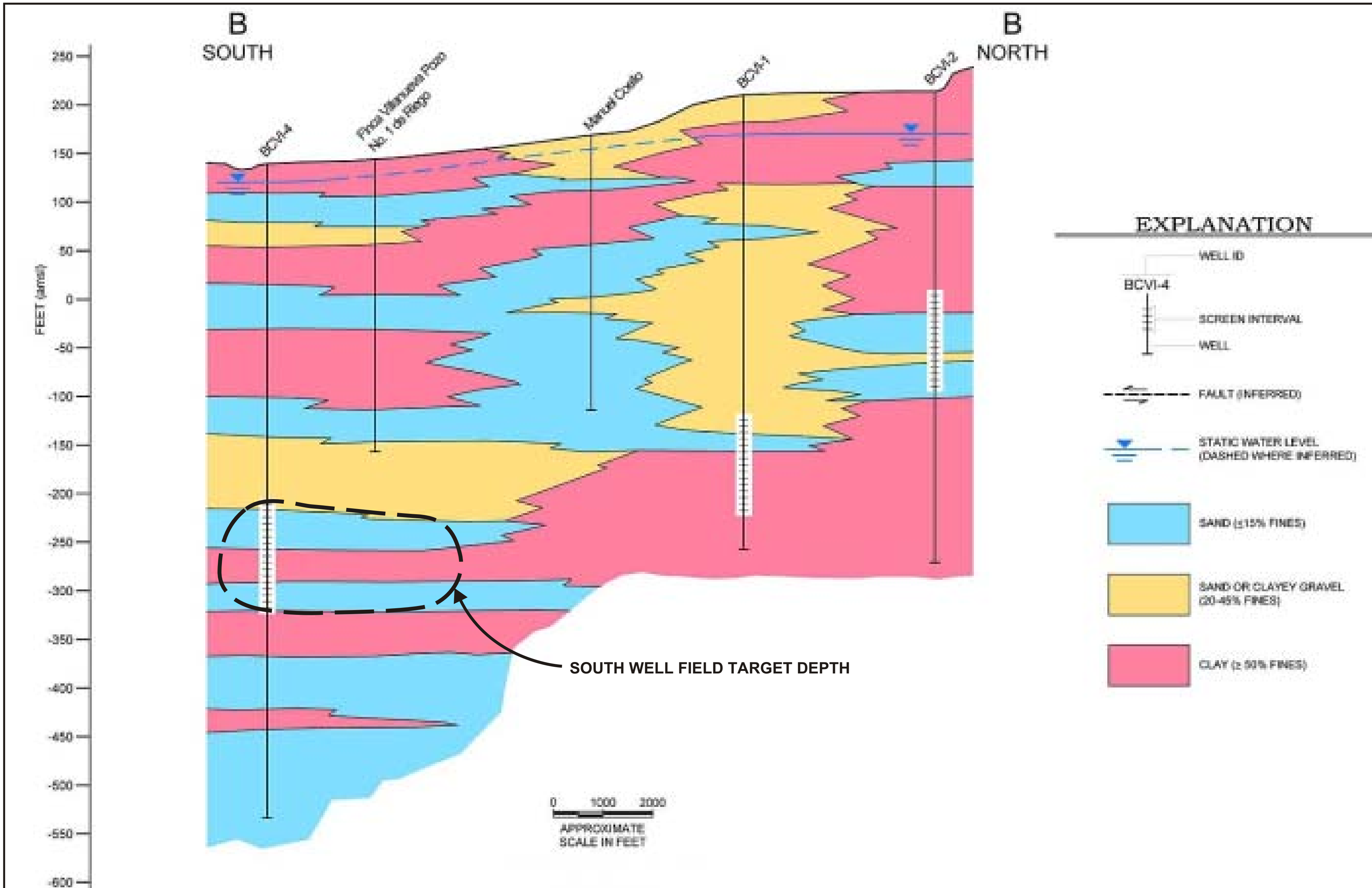
7. Establish control over well construction by others through municipal regulation that provides construction standards and well drilling reporting requirements.

8. Disinfect and retest the wells which have a presence of coliform and fecal coliform.

9. Prepare a water system expansion plan that defines needed improvements such as tanks and pipelines.



BROWN AND CALDWELL	DATE 7-3-02	SITE Villanueva, Republic of Honduras	FIGURE ES-1
	PROJECT 21143	TITLE Groundwater Resources Planning Map	



BROWN AND CALDWELL	DATE 7-2-02	SITE Villanueva, Republic of Honduras	FIGURE ES-2
	PROJECT 21143	TITLE Cross Section B-B’’	

1.0 INTRODUCTION

The United States Agency for International Development (USAID) retained Brown and Caldwell to provide architecture and engineering services as part of the Honduras Hurricane Reconstruction Program to assure the sustainability of permanent repairs and expansions of selected water supply systems damaged by Hurricane Mitch. Specifically, this project consists of performing groundwater monitoring studies for the Island of Utila, the Sula Valley (La Lima, Villanueva, and Choloma), and the resettlement community of Nueva Limón de la Cerca near Choluteca.

This Groundwater Resources Monitoring Report and Management Plan (Report) presents the results of the groundwater monitoring study and includes a groundwater resource management plan to help ensure the sustainable management of the groundwater resources of Villanueva, Honduras.

This chapter provides a description of the project objectives, scope of work, project background, and the report organization.

1.1 Project History and Objectives

The municipality of Villanueva is located in the northwestern portion of Honduras, as depicted on Figure 1-1. Villanueva depends almost exclusively on groundwater as its primary source of municipal water supply. It is anticipated that reliance on groundwater for the municipal water supply will increase as the population growth continues in the future. This project was initiated by USAID due to the increasing population in Villanueva, the need to quantify the available groundwater resources for sustainable development in this area, and the need to develop the groundwater resources while avoiding damage due to contamination and floods.

Figure 1-1. Site Location

This project is an important element in meeting overall USAID objectives in Honduras. The two objectives that are addressed best by this project are the sustainable improvements in family health and more responsive and effective municipal governments, as described below (USAID, March 2000).

Sustainable improvements in family health. One of this objective's desired results is the rehabilitation of water system facilities, given that access to potable water reduces child diarrheal deaths, especially in rural areas. The USAID performance indicator for this result is the percentage of rural water systems operating at the "A" level. This is defined as a system where a) water is disinfected, b) there is a water board that meets at least every three months, c) there is a water fee paid by users, d) there is a maintenance employee, and e) water is available from the system on a daily basis.

More responsive and effective municipal government services. This objective includes a desired result of increased coverage of public services, including potable water supply, as measured by the percent of inhabitants receiving public utility services.

To help meet the above objectives, this project evaluated the sustainable yield of the groundwater resources in the Villanueva area and developed a groundwater resources management plan to help ensure a sustainable municipal water supply for the urban area of Villanueva. Key components of the project include the following:

- identification of groundwater resources available to provide residents with a safe and sustainable water supply;
- development of a groundwater resource management plan and related tools that can be implemented and maintained by the municipality and its staff;
- training of local individuals in groundwater monitoring techniques, data collection, and database management for sustainable management of the groundwater resource; and
- project completion meetings with municipalities to discuss study results, present reports, and describe recommendations to help ensure sustainable water supplies.

1.2 Contract and Scope of Work

This study was conducted by Brown and Caldwell for the USAID under contract No. 522-C-00-01-00287-00, dated March 21, 2001. The scope of work for this project defines five phases under which to conduct the study. These five phases are described below.

Phase I – Analysis of Existing Information/Development of Conceptual Hydrogeological Model. This phase consisted of establishing consensus on the projects goals and objectives, data collection, preliminary conceptual hydrogeologic model development, and the identification of additional data needs.

Phase II – Field Investigation. This phase consisted of well drilling, aquifer testing, and water quality monitoring to fill data gaps and help provide data for refining the preliminary conceptual model. In addition, training was provided to local personnel in groundwater monitoring techniques.

Phase III – Hydrogeologic Modeling and Analysis. This phase consisted of refining the conceptual hydrogeologic model through quantitative groundwater modeling and analysis, and development of estimates of the long-term sustainable yield of water resources in the study area.

Phase IV - Database and Training in Monitoring and Database Management. This phase consisted of groundwater database development and database training of local municipal staff and preparation of training manuals for both the database and monitoring methods. The database is named the Water Resources Management System. The training manuals are included as Appendices D and E. This phase was executed concurrently with the other four phases.

Phase V – Final Report. This phase consisted of the development of a final project report that summarizes project data, activities, study results, and recommendations for sustainable management of the water resource in the area. The development of a groundwater resource management plan that includes appropriate measures for the development of the groundwater resources was also completed under this phase. This report represents the Phase V work product for the Villanueva urban area.

1.3 Report Organization

This report is organized into six chapters and associated appendices. The contents of each of the remaining chapters is briefly described below:

Chapter 2 – Background: This chapter provides a description of the community, climate, geology and soils, hydrogeology, wastewater management, and the regulatory setting.

Chapter 3 - Existing Water System and Water Demands: This chapter describes the existing water system and summarizes the historical demographics and projects future population and water use.

Chapter 4 - Groundwater Resources Evaluation: This chapter summarizes the methods, procedures, and results of the field investigation program. This chapter also presents a conceptual hydrogeologic model and a numeric groundwater model, recommends and numerically simulates well fields, and identifies potential sources of contamination to the groundwater resource. The training conducted on groundwater monitoring techniques is described in Appendix G.

Chapter 5 - Water Resources Management System: This chapter provides an overview, of the water resource database and management tool developed for Villanueva and presents instructions for using this tool to assist in the management of Villanueva's water resource. The training conducted on the use of the database is described in Appendix G.

Chapter 6 – Conclusions and Recommendations: This chapter presents the conclusions and groundwater resources management recommendations. This chapter also describes the scope for recommended additional studies, if needed. Finally, this chapter presents a recommended groundwater resource management plan and includes policy and institutional recommendations for sustainable management of the resource.

2.0 BACKGROUND

This chapter describes the geographic setting of the municipality of Villanueva as well as the, climate, geology and soils, hydrogeology, land use, wastewater management, and regulatory setting.

2.1 Geographical Setting

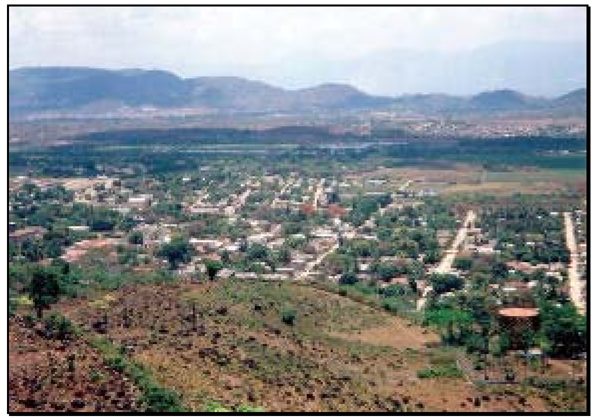


Figure 2-1. View of Villanueva from Upper Storage Tank

The municipality of Villanueva is located approximately 33 km (21 mi) south of San Pedro Sula. The Ulua River is located to the south of Villanueva. A view of the community is depicted on Figure 2-1. Villanueva consists of 15 neighborhoods, 20 urban districts, 20 rural districts, 33 small villages, and 58 country houses (Municipalidad de Villanueva Cortés, February 2001). Some of the outlying areas are served by small water systems that are not connected to the water system that serves the main urban area. This study focuses only on the water supply for the urban area. Figure 2-2 depicts a topographic map of the Villanueva area. The municipality of Villanueva is divided into urban, rural, agricultural and industrial areas, as illustrated on Figure 2-3. The industrial, rural, and agricultural areas are currently relatively undeveloped and are not served by the municipal water system.

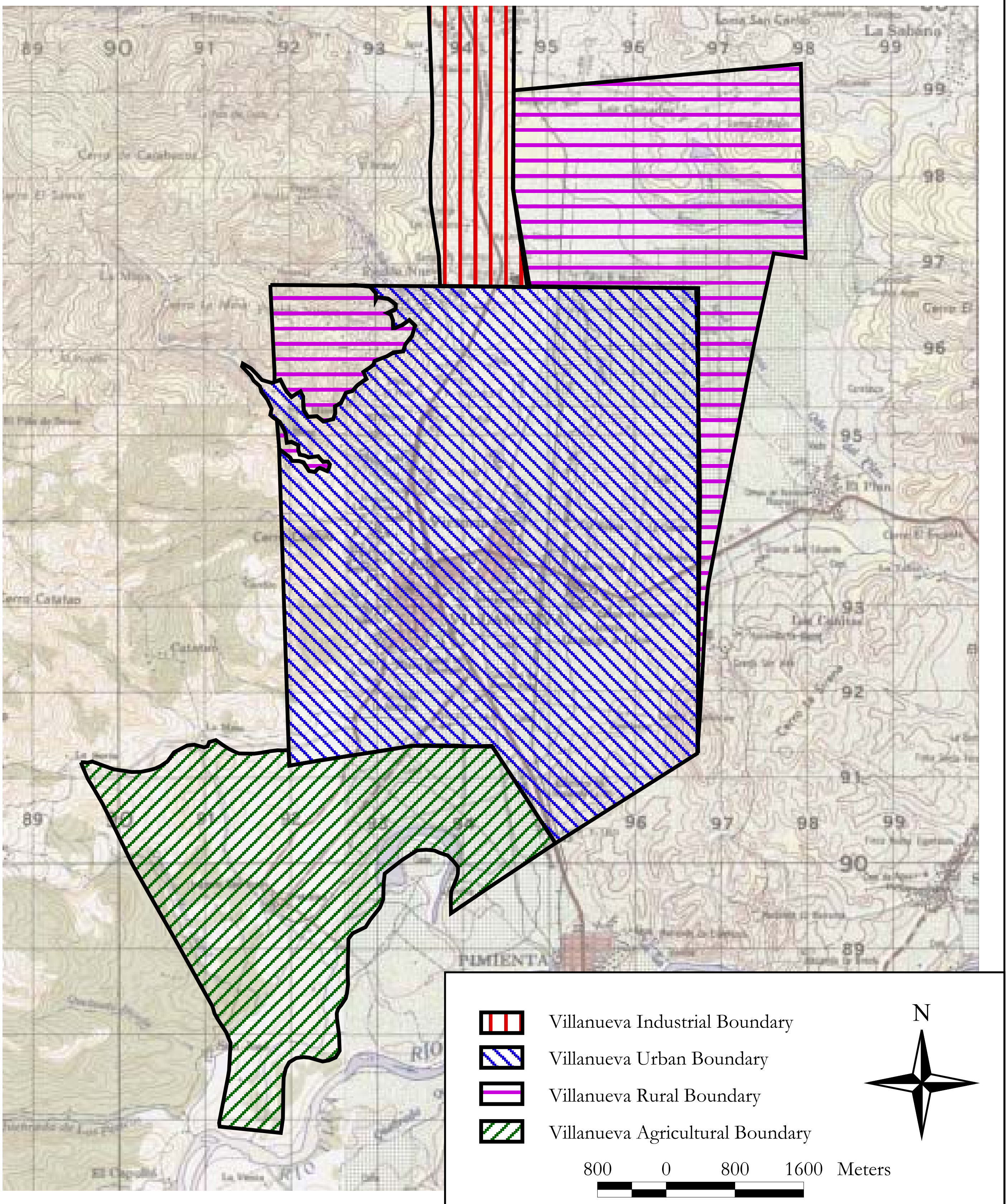
2.2 Climate

The entire country of Honduras lies within the tropics and consists of three different physiographic regions, referred to as the Caribbean lowlands, Pacific lowlands, and interior highlands. Villanueva lies within the Caribbean lowlands, which have a tropical wet climate with consistently high temperatures and humidity, and receives approximately 2,400 millimeters (94 inches) of precipitation a year. Most rain falls between April and November, (Library of Congress, Federal Research Division, 1993). Due to the projects short time frame and availability of historical precipitation data, Brown and Caldwell did not collect any supplemental rainfall data. Villanueva has a climate similar to San Pedro Sula, which has an average temperature of about 30-35 degrees Celsius.

2.3 Geology and Soils

Villanueva is situated along the western portion of the Sula Valley, a prominent north-south trending graben located in the north-central portion of the country. A graben is defined as a downward dropped valley with faults on both sides. The valley is bound by high-angle normal faults to the east and west. A number of normal faults and strike-slip faults are present which trend east-west, perpendicular to the valley. The southern portion of the Sula Valley is believed to be represented

BROWN AND CALDWELL	DATE 2-13-02	SITE Villanueva, Republic of Honduras, C.A.	FIGURE 2-2
	PROJECT 21143	TITLE Topographic Map Showing Villanueva and Southern Portion of Sula Valley	



BROWN AND CALDWELL	DATE 3/15/2002	SITE Villanueva, Honduras, C.A.	FIGURE 2-3
	PROJECT 21143	TITLE Urban, Rural, Industrial, Agricultural and Municipal Boundaries	

by two half grabens where the down-thrown block of the valley surrounding Villanueva is separated from the main Sula Valley down-thrown block by the Siren Hills to the east. The Villanueva Valley portion is approximately 2 to 5 kilometers (km) (1 to 3 miles (mi)) in width and is bound to the east and west by uplifted Cretaceous-age limestones of the Yojoa group and is overlain by Tertiary-age volcanic rocks of the Matagalpa formation.

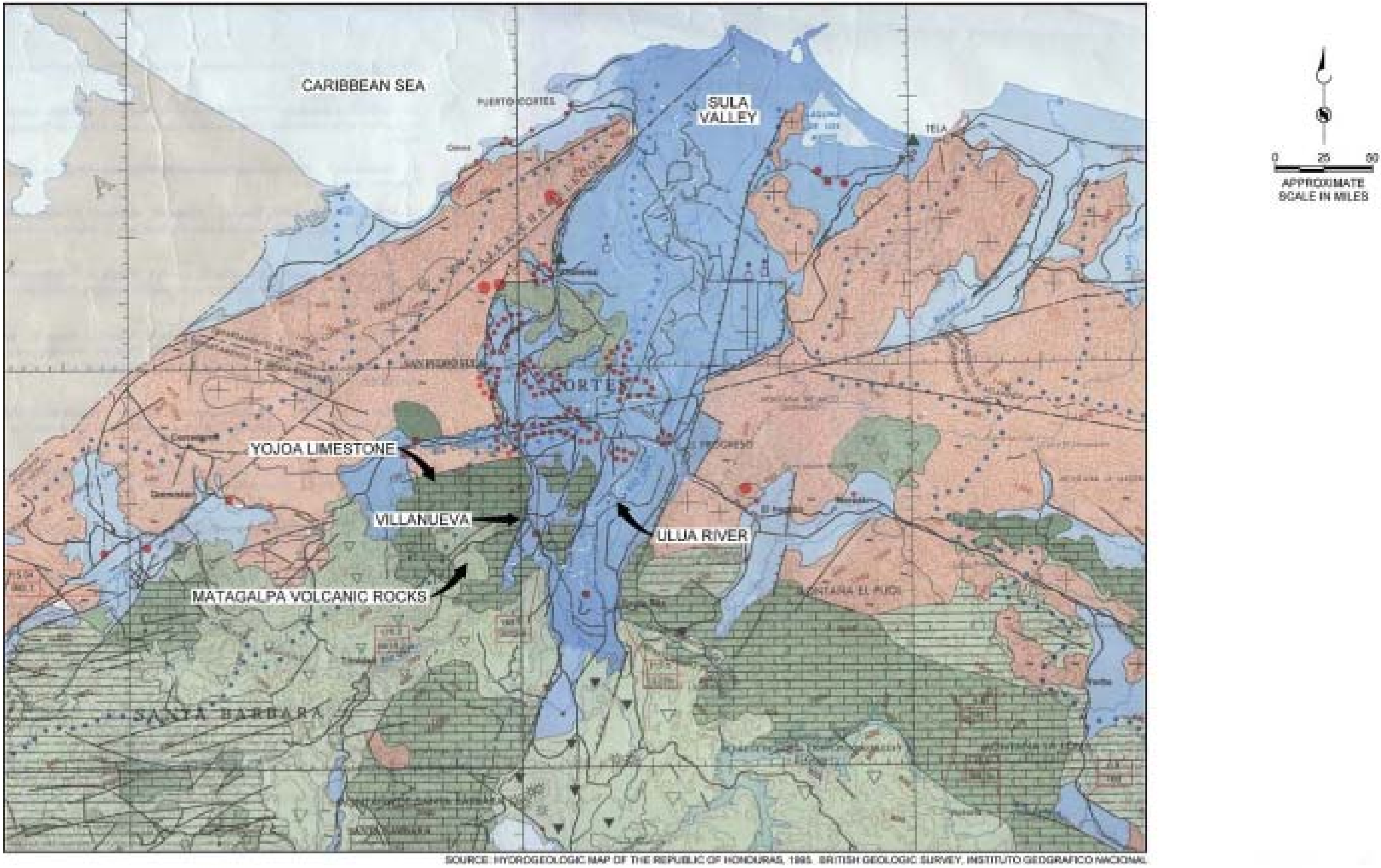
The Ulua River is located approximately 5 km (3 mi) south of Villanueva. The Ulua River basin comprises one of the most extensive watersheds in Honduras. The river enters the southern portion of the Villanueva Valley from the highlands to the southwest and flows eastward. Prior to the formation of the Sula Valley, the area was represented by a large uplifted plateau, and was drained by a series of deeply incised river channels. Subsequent regional plate extension processes lead to normal faulting of surrounding highlands and the formation of the graben areas of the Sula Valley, which disrupted previous drainage patterns. During this time, the ancestral Ulua River continued on an eastward flow direction, dissecting a wide channel through the Siren Hills, possibly following faults or fracture traces that trend perpendicular to the valley. Within the Sula Valley, the river presently flows north-northeast meandering across the Sula Valley before reaching the Caribbean Sea.

Collectively, the Villanueva Valley and Sula Valley consist of Quaternary alluvial deposits. These deposits are comprised of interbedded discontinuous beds of alluvial and fluvial channel and floodplain sands silts, clays and gravels eroded from surrounding highlands. The fluvial materials can be subdivided into two depositional settings: the recent Ulua River fluvial deposits and older buried channel deposits, which also comprise valley margin alluvial materials.

2.4 Hydrogeology

The Villanueva Valley is bounded to the east and west by mountainous areas comprised of the Yojoa Group limestone, and overlying Matagalpa volcanic rocks in some areas. Generalized geologic maps prepared by the Instituto Geografico Nacional (Figure 2-4) show the limestone contains sinkholes and other carbonate dissolution features. The karst limestone together with the fractured volcanic rocks, serve as the major surface and groundwater recharge areas for the alluvial materials of the valley. Surface water infiltrates into fracture networks and dissolution cavities of the uplands providing groundwater recharge to the valley bedrock and alluvial materials. Groundwater from the western uplands generally flows to the east, and at least some of the groundwater from the Siren Hills flows to the west. Once the groundwater from the upland areas enters the valley alluvium, groundwater flow will generally begin to move in a southerly direction, towards the Ulua River, which serves as the major groundwater discharge point for the valley hydrologic system.

North of the community, several small streams drain into the western uplands into the valley. These are referred to as La Mina, El Pinto, and Guanacaste. These streams are intermittent, and flow only during heavy thunderstorms or during the winter. Since water from these streams is diverted upstream to provide water supply for the community, the streams do not represent a significant source of recharge for areas in the valley.



BROWN AND CALDWELL	DATE 2-13-02	SITE Villanueva, Republic of Honduras, C.A.	FIGURE 2-4
	PROJECT 21143	TITLE Geologic Map - Sula Valley	

Groundwater occurs within the valley margin alluvium, the buried channel deposits, and the Ulua River alluvium. Currently, 11 wells are screened within the valley margin deposits. Groundwater production from these wells reportedly ranges from 114 to 379 liters per minute (lpm) (30 to 100 gallons per minute (gpm)) each, with an average yield per well of 216 lpm (57 gpm). Based on available well information, aquifers within the valley margin deposits are limited in nature and are unable to produce sufficient supplies of groundwater.

Six wells are reportedly screened within the buried channel deposits, which is assumed to be the primary water bearing unit in Villanueva. Groundwater production from these wells range from approximately 189 to 1,893 lpm (50 to 500 gpm) each with an average yield of approximately 719 lpm (190 gpm) per well. The available information on the buried channel aquifer is limited, resulting in the need for additional information to characterize the lateral extent of the aquifer system. It is believed that these aquifers are linear in nature and may extend along the axis of the valley.

The Ulua River alluvium extends from the southern edge of the Villanueva city limits to the Ulua River. These materials are comprised of channel and flood plain deposits of the Ulua River. Boring logs completed within the Ulua River alluvium indicated that the upper 76 meters (m) (250 feet (ft)) of alluvial materials are characterized as a fining upward sequence of alluvial and fluvial deposits. The upward 3 to 6 m (10 to 20 ft) of alluvial materials are characterized as inter-bedded clayey-silts and silts. These materials grade into inter-bedded silts and fine to medium sands from approximately 6 to 30 m (20 to 100 ft). Below 30 m (100 ft), approximately 46 m (150 ft) of inter-bedded fine-, medium-, to course-grained sands and gravels have been observed.

2.5 Land Use

Land is used in Villanueva for residential, industrial, and agricultural purposes. Originally an agricultural community with large sugar cane plantations, Villanueva is now host to considerable industrial development, including the manufacture of clothing and related items, food processing, and a concrete cast plant.

2.6 Wastewater Management

An understanding of the wastewater management is important because certain disposal practices can impact groundwater quality. There is a wastewater collection system in the southern part of the City of Villanueva. A gravity piping network collects the waste-water and delivers it to an anaerobic lagoon southeast of the city, adjacent to the highway. The lagoon has the capacity to serve 25,000 people, is clay lined, and consists of three chambers. A baffle system within the chambers creates a detention time of approximately 24 hours before draining the effluent into an earthlined channel that eventually drains to the river.

A majority of the residents living on the hills in the northern portion of the city are not connected to a centralized wastewater system. These residents rely on latrines for their wastewater disposal.

2.7 Regulatory Setting

The water system in Villanueva is owned by the municipality, and technical assistance is currently provided by Servicio Autonomo Nacional de Acueductos y Alcantarillados (SANAA). SANAA is an autonomous Honduran governmental entity that operates the urban water and waste water systems for Tegucigalpa and 15 other municipalities.

The water systems in Honduras are regulated by the Honduran Ministry of Health. The drinking water standards are equivalent to standards defined by the World Health Organization (WHO). Currently, drinking water standards are not enforced and water compliance monitoring and reporting are not required in Honduras.

The Panamerican Health Organization provides technical support to municipalities through the Ministry of Health for water issues. Some other organizations have been formed in Central America recently to share experiences in water and sanitation management with municipalities.

3.0 DESCRIPTION OF EXISTING WATER SYSTEM AND WATER DEMANDS

This chapter describes the existing water supply system and municipal water demands in Villanueva. The information was obtained from reports prepared by others, discussions with municipal representatives, and our field reconnaissance.

3.1 Water Supply System

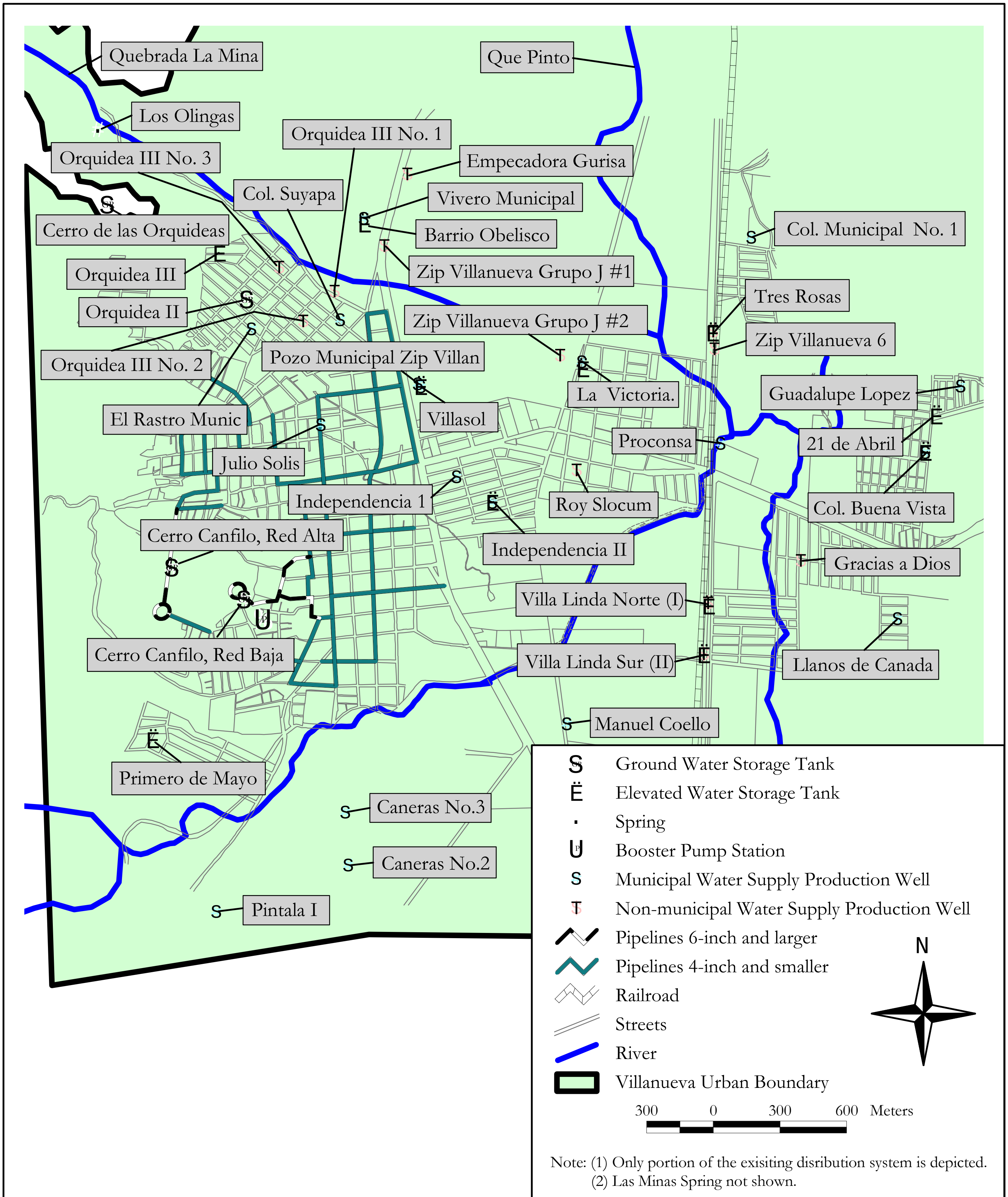
This section describes the main components of the Villanueva water system. The water system is owned and operated by the municipality of Villanueva. The sources of water supply consist of mainly groundwater and a small spring source. Currently there is no treatment or disinfection of the water prior to distribution. Figure 3-1 depicts the locations of the key water system facilities. The municipal wells, private wells, surface water supplies, booster pump station, storage facilities, and piping system are described below.

3.1.1 Municipal Water Supply Wells. Sixteen municipal wells provide the water supply for Villanueva with a combined capacity of 193 lps (2,662 gpm). Four of the wells are the major sources of supply. Table 3-1 summarizes key information regarding the existing wells. Table 3-1 also presents the estimated hours of pumping per day and resulting daily production of each well based on information collected during the field investigation. Figure 3-2 depicts the two largest producing wells that are located in the sugar cane field south of Villanueva.

Table 3-1. Municipal Well Information

Name	Capacity		Daily pumping time, hours	Daily production		Well depths, bgs	
	lps	gpm		lps	gpm	m	ft
Buena Vista	4	60	24	4	60	—[b]	—[b]
Barrio Suyapa	4	60	24	4	60	76	250
Cañeras 2	38	600	24	38	600	76	250
Cañeras 3	25	400	24	25	400	61	200
Col. Municipal #1	4	60		—[b]	—[b]	—[b]	—[b]
Col. Victoria	8	120	24	8	120	59	195
Guadalupe Lopez	9	150	24	9	150	79	260
Independencia I	2	30	24	2	30	—[c]	—[c]
Independencia II	1	15	1	—[b]	—[b]	—[b]	—[b]
Julio Solis	3	48	24	3	48	—[b]	—[b]
Manuel Coello	13	202	10	5	84	82	270
Pintala I	25	400	2	2	33	73	240
Pintala II[a]	25	400	24	25	400	67	220
Rastro Municipal	4	60	24	4	60	—[b]	—[b]
Villa Sol	2	27	23	2	25	56	184
Vivero Municipal	2	30	24	2	30	—[b]	—[b]
Total	168	2,662	—	132	2,100	—	—

[a]Well not shown on water system figure. lps= liters per second bgs = below ground surface
[b]Unknown m = meter gpm = gallons per minute
Note: Following wells not included because of no information: Llanos de Canada, Pozo Municipal Zip Villanueva, Proconsa, La Canera Campo de Pozo No. 1, and Rancho Chico Cocodrilos No. 2.



BROWN AND CALDWELL	DATE 6/19/2002	SITE Villanueva, Honduras, C.A.	FIGURE 3-1
	PROJECT 21143	TITLE Existing Water System	

Figure 3-2. View of Principal Municipal Wells – Cañeras No. 2 and Cañeras No. 3

3.1.2 Non-Municipal Water Supply Wells. Seven water supply wells have been identified with a combined capacity of 35 lps (555 gpm) that provide supplemental water to private industries and businesses within Villanueva. These wells are operated by community water boards and do not supply water to the municipal distribution system. Table 3-2 summarizes the information that was available for the non-municipal wells in Villanueva.

Table 3-2. Non-Municipal Well Information

Name	Capacity		Daily pumping time, hours	Daily production		Well depths, bgs	
	lps	gpm		lps	gpm	m	ft
Gracias a Dios	3	55	18	3	41	--[a]	--[a]
Villa Linda Norte	7	105	24	7	105	91	300
Villa Linda Sur	11	175	7	3	51	--[a]	--[a]
Orquidea #1	4	60	24	4	60	76	250
Orquidea #2	4	60	24	4	60	--[a]	--[a]
Orquidea #3	3	50	24	3	50	122	400
Las Tres Rosas	3	50	12	2	25	--[a]	--[a]
Total	35	555	--	25	392	--	--

[a]Unknown
bgs = below ground surface
ft = feet
gpm = gallons per minute
lpm = liters per minute
m = meter
Note: Following wells not included because of no information: Zip Villanueva Grupo J No. 1 and 2, Zip Villanueva 6, Roy Slocum, and Empeador Gurisa.

3.1.3 Surface Water Facilities. The surface water supply consists of two spring sources, Las Minas and Los Olingos. These spring sources are located in the hills northwest of Villanueva. Los Olingos is shown on Figure 3-1. Las Minas is not tied to the municipal water system. The water from Las Minas is piped down the hill into a spring catchment. Los Olingos is tied directly to the municipal water system and serves the northeast portion of town (the lower pressure zone) by gravity through a 102-mm (4-inch) diameter polyvinyl chloride (PVC). Figure 3-3 depicts the Los Olingos spring.

Figure 3-3. Los Olingos Spring Water Supply Source

3.1.4 Booster Pump Station. The Villanueva distribution system has one booster pumping station, which pumps water from the lower 1.1 million liters (300,000 gallon) storage tank (known as Cerro Canfilo, Red Baja) to the upper 189,000 liter (50,000 gallon) storage tank (known as Cerro Canfilo, Red Alta). The booster pumping station has a design capacity of 300 gpm, and operates approximately 18 hours per day. Figure 3-4 depicts the booster pumping station and the 1.1 million liter (300,000 gallon) tank.

Figure 3-4. Booster Pumping Station and Lower Storage Tank (Cerro Canfilo, Red Baja)

3.1.5 Water Storage Facilities. Water is currently stored in nine municipal storage tanks at various locations within the municipality of Villanueva, as illustrated on Figure 3-1. The municipal storage tanks have a total capacity of 2,138,319 liters (564,884 gallons), as presented in Table 3-3. Figure 3-5 depicts the upper storage tank.

Six water storage tanks are used for storage of water from non municipal wells. The non municipal storage tanks have a total capacity of greater than 143,000 liters (37,888 gallons), based on available data for three of the six tanks, as presented in Table 3-4. These tanks are not connected to the municipal water system.

Table 3-3. Municipal Storage Tanks

Name	Volume		Type of tank
	liters	gallons	
Primero de Mayo	113,562	30,000	elevated, concrete
Cerro Canfilo (Red Baja)	1,135,624	300,000	ground, metal
Cerro Canfilo (Red Alta)	189,271	50,000	ground, concrete
Barrio Obelisco	107,695	28,450	elevated, concrete
Buena Vista	113,562	30,000	elevated, concrete
Villa Sol	37,854	10,000	elevated, metal
21 de Abril	189,271	50,000	elevated, concrete
Independencia	62,209	16,434	elevated, metal
La Victoria	189,271	50,000	elevated, metal
Total	2,138,319	564,884	--

Source: Asesores Técnicos en Ingeniería y Ciencias Ambientales (ATICA), 2001. *Información de Tanques.xls via email.*

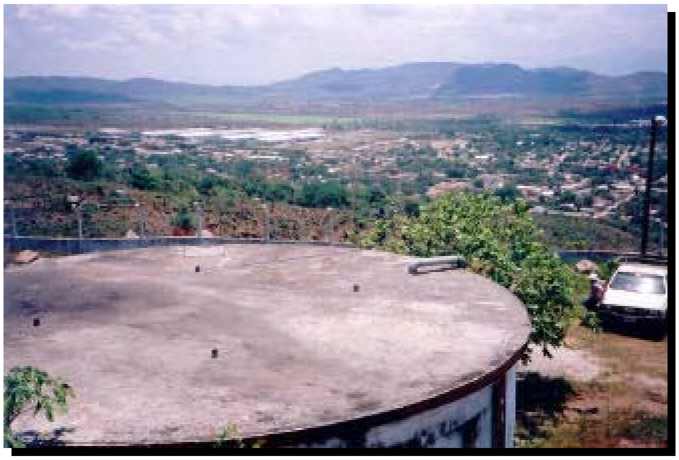


Figure 3-5. Upper Water Storage Tank (Cerro Canfilo, Red Alto)

3.1.6 Piping System. The Villanueva distribution system consists primarily of 76-mm to 203-mm (3-in to 8-in) diameter PVC pipeline. The distribution system consists of two pressure zones. The majority of the area is served by the lower pressure zone. The upper pressure zone serves a small area on the west side of Villanueva. System pressures are estimated to range from 20 to 58 pounds per square inch.

Table 3-4. Private Storage Tanks

Name	Volume		Type of tank
	liters	gallons	
Cerro de las Orquideas	--		ground, metal
Las Tres Rosas	37,854	10,000	elevated, metal
Orquidea II			ground, metal
Orquidea III	--		elevated, metal
Villa Linda Norte	52,784	13,944	elevated, metal
Villa Linda Sur	52,784	13,944	elevated, metal
Total	143,422	37,888	--

Source: Asesores Técnicos en Ingeniería y Ciencias Ambientales (ATICA), 2001. *Información de Tanques.xls via email.*

3.2 Historical and Projected Water Demands

Water demand projections provide the basis for sizing and staging future water facilities. Estimates of current water use combined with projections of residential population, provide the basis for estimating future water requirements. This section presents a summary of demographic information and water use data and the resulting projections of future water needs for Villanueva.

3.2.1 Demographics. The municipal water system serves domestic, commercial, industrial, and public customers, as presented in Table 3-5. There are 8,159 active connections in the Villanueva water system (Municipalidad de Villanueva, Departamento de Cortés, Division de Servicios Publicos). In 1998, the Villanueva urban population was 25,057 and there were 4,767 homes within the urban boundaries served by the Villanueva municipal water system (Municipalidad de Villanueva Departamento de Cortés. 1998). This results in an average of 3.1 people per connection and 5.3 people per household. It is not known why the number of domestic connections in Table 3-5 is much greater than the reported number of homes.

Table 3-5. Municipal Connections by Classification

Classification	Connections
Domestic	7,006
Commercial	1,141
Industrial	12
Total	8,159

Source: Municipalidad de Villanueva, Departamento de Cortés, Division de Servicios Publicos. Abonados por Categorias y por Servicios.

Since published population projections prepared by others have not been identified for use in this study, the future population has been projected as part of this study. The population annual growth rate assumed for 2000 through 2010, is based on the historical growth rate of the developed land area occurring from 1981 to 2000. For this study, it is assumed that the growth of developed area can serve as a surrogate for population growth. The 1981 developed land area was measured from the 1981 topographic map for the Villanueva area (Instituto Geográfico Nacional, Tegucigalpa, D.C. Honduras). The 2000 developed land area was measured from the March 2000 aerial photograph (USGS, March 2000, black and white aerial photograph). The developed land area in 1981 and 2000 are illustrated on Figure 3-6. These land areas are presented in Table 3-6.

Table 3-6. Developed Land Area

Year	Land area	
	acres	km^2
1981[a]	179	0.73
2000[b]	666	2.69

[a] Based on developed area in the 1981 Topographic Map Instituto Geografico Nacional, Tegucigalpa, D.C., Honduras.
[b] Based on developed area in the USGS March 2000 aerial photograph

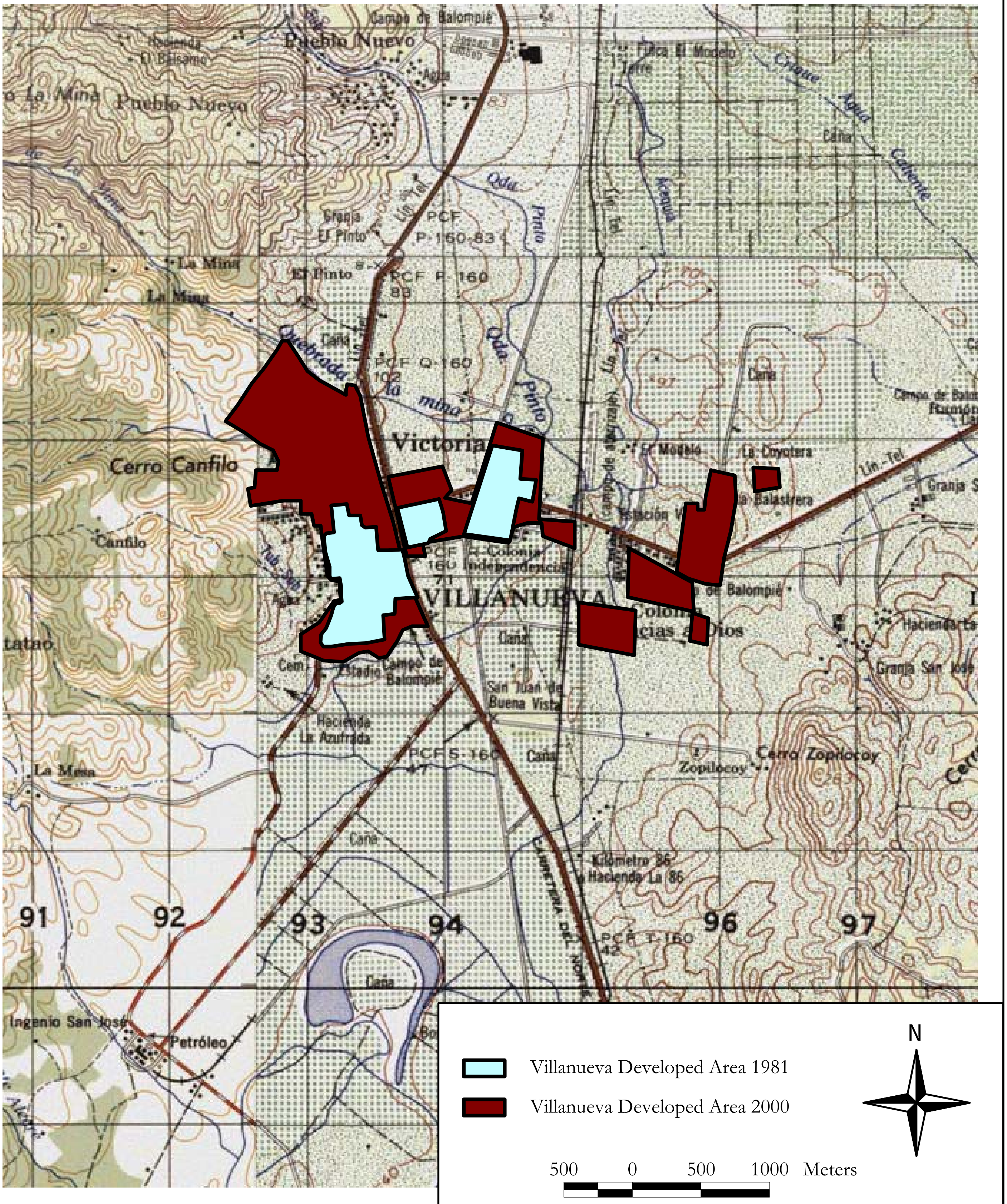
From 1981 to 2000, the developed land area expanded at an average growth rate of seven percent per year. The current population density is approximately 38 people per acre.

It is assumed for this study that the 1981 to 2000 historical growth rate will continue through 2010. It is unlikely that this rapid growth rate will be maintained over the long-term. As communities become larger, their annual growth rates tend to decline. This study assumes that the growth rate for Villanueva will decrease following the year 2010 to be equivalent to that of the nearby and much larger city of San Pedro Sula, which is 5.48 percent per year (REPAMAR, 2000). The historical and projected population are presented in Table 3-7 and illustrated on Figure 3-7.

Table 3-7. Projected Population within Villanueva Urban Boundary

Year	Population
2000	28,822
2005	40,901
2010	58,041
2015	76,337
2020	100,399

Note: Population projection based on 7 percent annual growth rate through 2010, and 5.5 percent thereafter.



BROWN AND CALDWELL	DATE 6/14/2002	SITE Villanueva, Honduras, C.A.	FIGURE 3-6
	PROJECT 21143	TITLE Urban Growth	

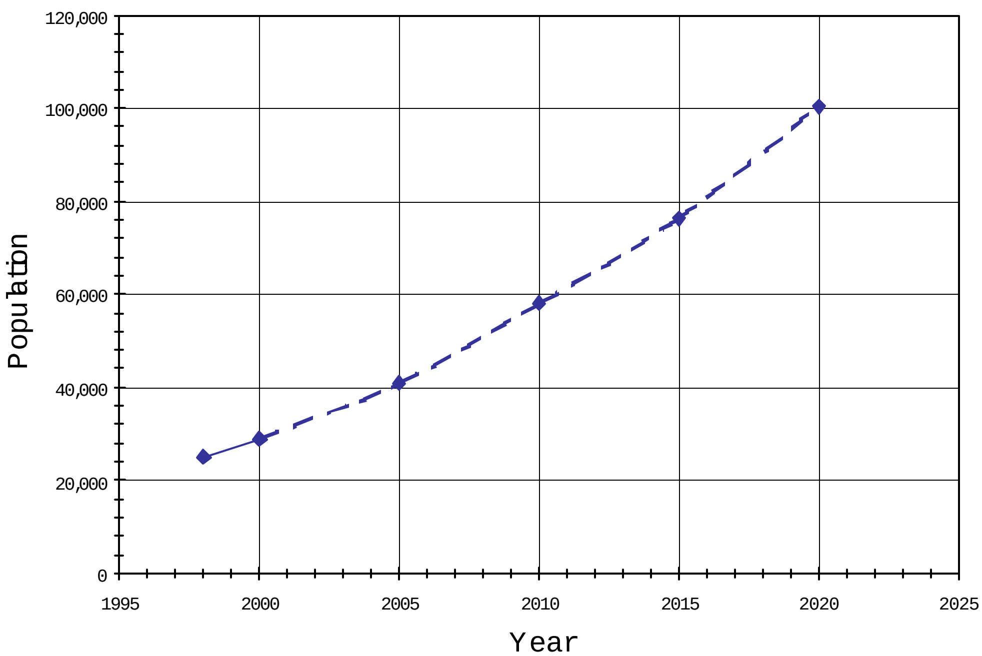


Figure 3-7. Projected Villanueva Urban Area Population

3.2.2 Historical Water Use. Water production is the volume of water measured at the source, which includes all water delivered to residential, commercial, and public authority connections, as well as unaccounted-for water. Water production information is not available because most of Villanueva's wells are not metered. The high production wells located at Las Cañeras have meters. An estimate of current (year 2002) average annual municipal water production based on the number of hours each well is pumping (Table 3-1) is 11 million liters per day (mld) (3.0 million gallons per day (mgd)). This is approximately equivalent to an estimate of current water production based on a per capita production including system losses of 341 liters per capita per day (lpcd) (90 gallons per capita per day (gpcd)) and a year 2002 estimated population of 33,000. These water demand estimates do not include water pumped from the non-municipal wells. The groundwater flow model presented in Appendix C used an average annual groundwater extraction rate including the non municipal wells of 153 lps (2,427 gpm) or 13.2 mld (3.5 mgd).

Daily demand fluctuates throughout the year based primarily on seasonal climate changes. Water demands are higher in the dry season and decrease in the wet season. System production facilities must be sized to meet the demand on the maximum day of the year, not just the average. The maximum day peaking factor, which is defined as the one day of highest water use during a one-year period divided by average daily use, is estimated to be 1.2 for the purposes of this study, based on common engineering practice. Based on this assumption, the year 2002 estimated maximum day water demand is 13.7 mld (3.6 mgd).

Unaccounted-for water use is unmetered water use, such as from fire protection and training, system and hydrant flushing, sewer cleaning, construction, system leaks, and unauthorized connections. Unaccounted-for water can also result from meter inaccuracies. The water system in Villanueva is not metered, therefore, data are unavailable for determining the percent of unaccounted-for water.

3.2.3 Unit Water Use. Unit water use factors are used to estimate future water needs, based on the population projections discussed previously. Future water needs are determined using the population projections within the Villanueva service area, coupled with a unit water use factor per person.

Unit water use in nearby San Pedro Sula, one of the largest cities in Honduras, is estimated to be 379 lpcd (100 gpcd). This includes San Pedro Sula's 52 percent unaccounted-for water use (REPAMAR, 2000). In San Pedro Sula, a range from 303 to 454 lpcd (80 to 120 gpcd) is typically used in designs. It is assumed for this study that the unit water use in Villanueva is 341 lpcd (90 gpcd). This assumed unit water use includes leakage in the distribution system.

3.2.4 Projected Water Demands. Water demands through the year 2020 were estimated based on the assumed unit water use factor of 90 gpcd and the urban area population projections. These water demand projections are presented in Table 3-8 and shown in Figure 3-8. By 2020, average annual water demands are expected to increase from 9.8 mld (2.6 mgd) in 2000 to 34.1 mld (9.0 mgd) for the year 2020. The year 2020 maximum day water demand is expected to be 40.9 mld (10.8 mgd). These demand projections do not include demands supplied by non municipal wells. Impacts to water use due to any conservation measures implemented in the future are not reflected in the projected water demands.

Table 3-9 presents a comparison of water demands versus source capacity. The required supply is based on the assumption that wells are limited to a maximum of 20 hours per day of operation.

Table 3-8. Projected Water Demands for Villanueva Urban Area

Year	Average day water use		Maximum day water use[a]	
	mld	mgd	mld	mgd
2000	9.8	2.6	11.7	3.1
2005	14.0	3.7	16.6	4.4
2010	19.7	5.2	23.5	6.2
2015	26.1	6.9	31.4	8.3
2020	34.1	9.0	40.9	10.8

[a] Maximum day projected water demands based on assumed 1.2 maximum day peaking factor.

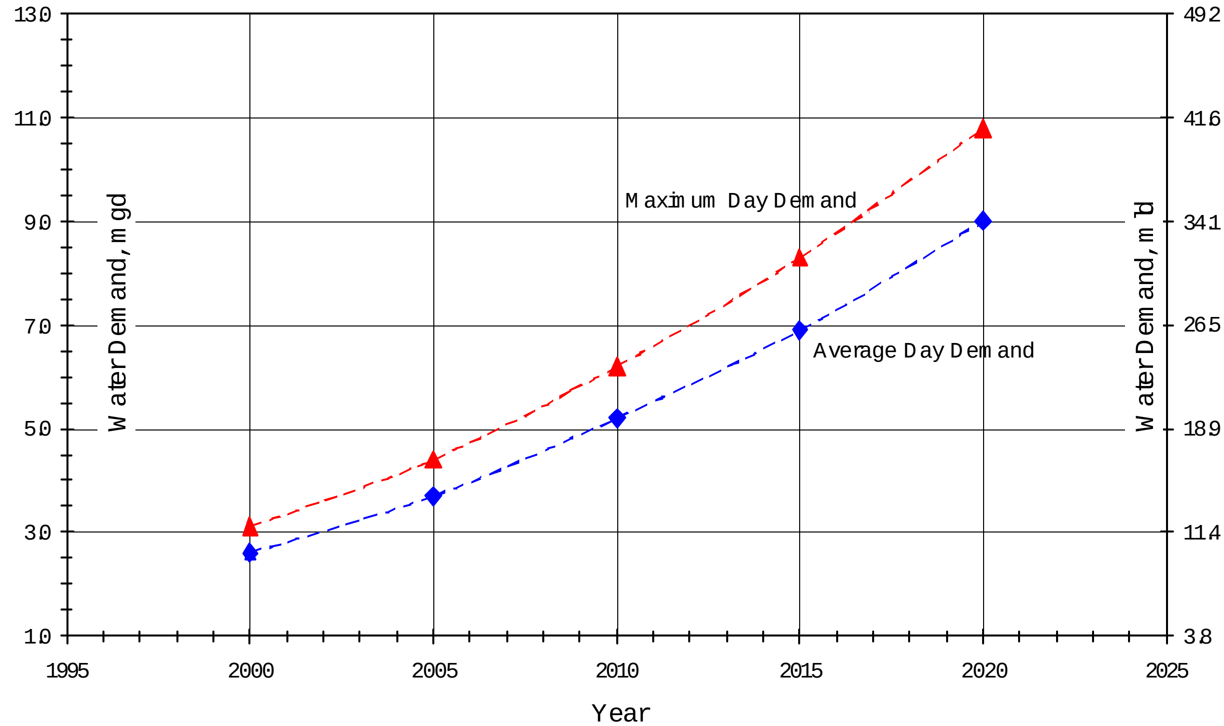


Figure 3-8. Projected Municipal Water Demand for Villanueva Urban Area

Table 3-9. Comparison of Water Requirements to Supply

	2002, gpm	2020, gpm
Average day demand	1,805	6,250
Maximum day demand[a]	2,153	7,500
Required supply capacity[b]	2,584	9,000
Available capacity[c]	2,662	2,662
Deficit[d]	0	6,338

[a] Maximum day demand based on assumed 1.2 maximum day peaking factor.
[b] Based on 20 hour/day pumping and meeting maximum day demand.
[c] Identified existing municipal wells capacity.
[d] Required well capacity to meet maximum day demand.

4.0 GROUNDWATER RESOURCE EVALUATION

The groundwater resource evaluation for Villanueva consisted of the review and analysis of existing geologic, hydrogeologic, and groundwater resource information for the area. Following the initial records review, a site reconnaissance of the area was conducted, followed by the development of a conceptual model, and the performance of a field investigation which included drilling and testing of test wells to explore deep hydrogeologic conditions in the valley. Following data collection and interpretation, a numeric groundwater flow model was developed using data obtained during this evaluation. This chapter presents the results of the groundwater evaluation at Villanueva.

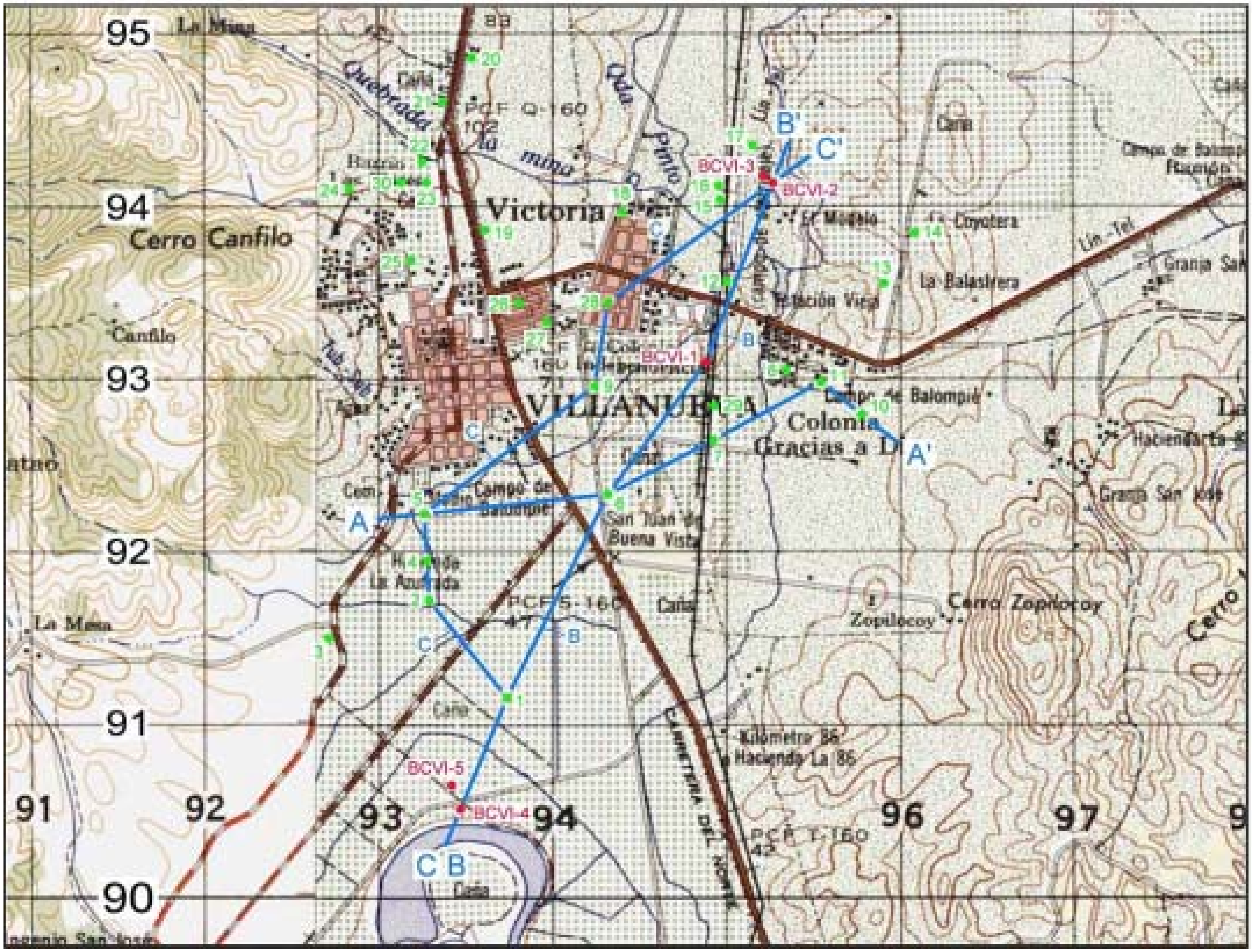
4.1 Conceptual Hydrogeologic Model

A conceptual hydrogeologic model was prepared for this project as a step before the start of the field investigation work. The conceptual model prepared in July 2001 is presented in Appendix A.

The conceptual model for Villanueva was developed based on the understanding that the upland areas surrounding the Villanueva Valley serve as the major surface and groundwater recharge areas for the buried alluvial materials. Precipitation recharge to the western and eastern highlands flows through bedrock and sediments, toward the valley, and ultimately discharges to the Ulua River, the major discharge area for the valley hydrologic system.

Based on information from local drilling companies, representatives from the municipality, and residents, groundwater production is known to occur from the alluvial deposits and the deeper buried ancestral river deposits. However, detailed information regarding each of these aquifers was limited. The alluvial deposits located along the flanks of the uplands were suspected to be of limited areal extent and produce only moderate water supplies. However, limited information indicated the buried channel deposits were more extensive, linear in shape, and extended along the entire axis of the valley. It was suspected the Ulua River alluvium presented the greatest potential for producing good well yields, however, more information is needed to assess whether this aquifer would be able to meet sustainable yields for the growing community.

Following the development of the conceptual model, geologic cross-section profiles were constructed, as located on Figure 4-1, from lithology described at newly installed wells as well as previously existing municipal and private wells. The cross-sections presented as Figure 4-2 and Figure 4-3 illustrate the channel and flood plain deposits of the Ulua River. In general, the areas to the west of the municipality exhibit a fining-upward sequence of clayey-gravels, clayey-sands, and sands. Toward the east, the sediments are characterized by interbedded clays and sands with some pockets of clayey-sands and clayey-gravels at approximately 15 and 76 m (50 and 250 ft) bgs (Figure 4-2). To the south of the municipality, interbedded sands and clays dominate with two minor pockets of clayey-sand encountered at depths of approximately 30 and 91 m (100 and 300 ft) bgs (Figure 4-3). To the north, the sediments are dominated by clays with some water producing clayey-sands and sands documented from approximately 69 to 91 m (225 to 300 ft) bgs (Figure 4-3).



0 1000 2000
APPROXIMATE SCALE IN FEET

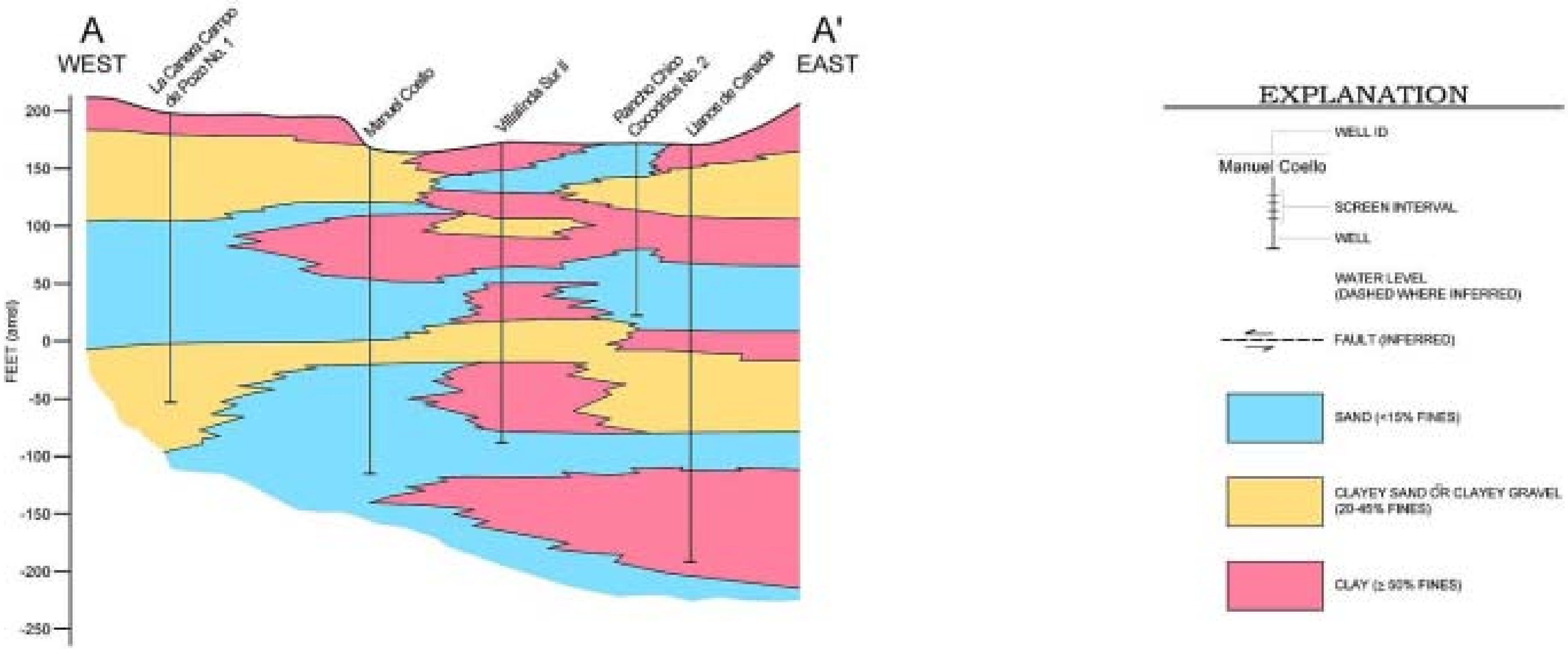
EXPLANATION

- BCVI-4 — APPROXIMATE WELL LOCATION / WELL ID
- A —— A' LINE OF GEOLOGIC CROSS-SECTION

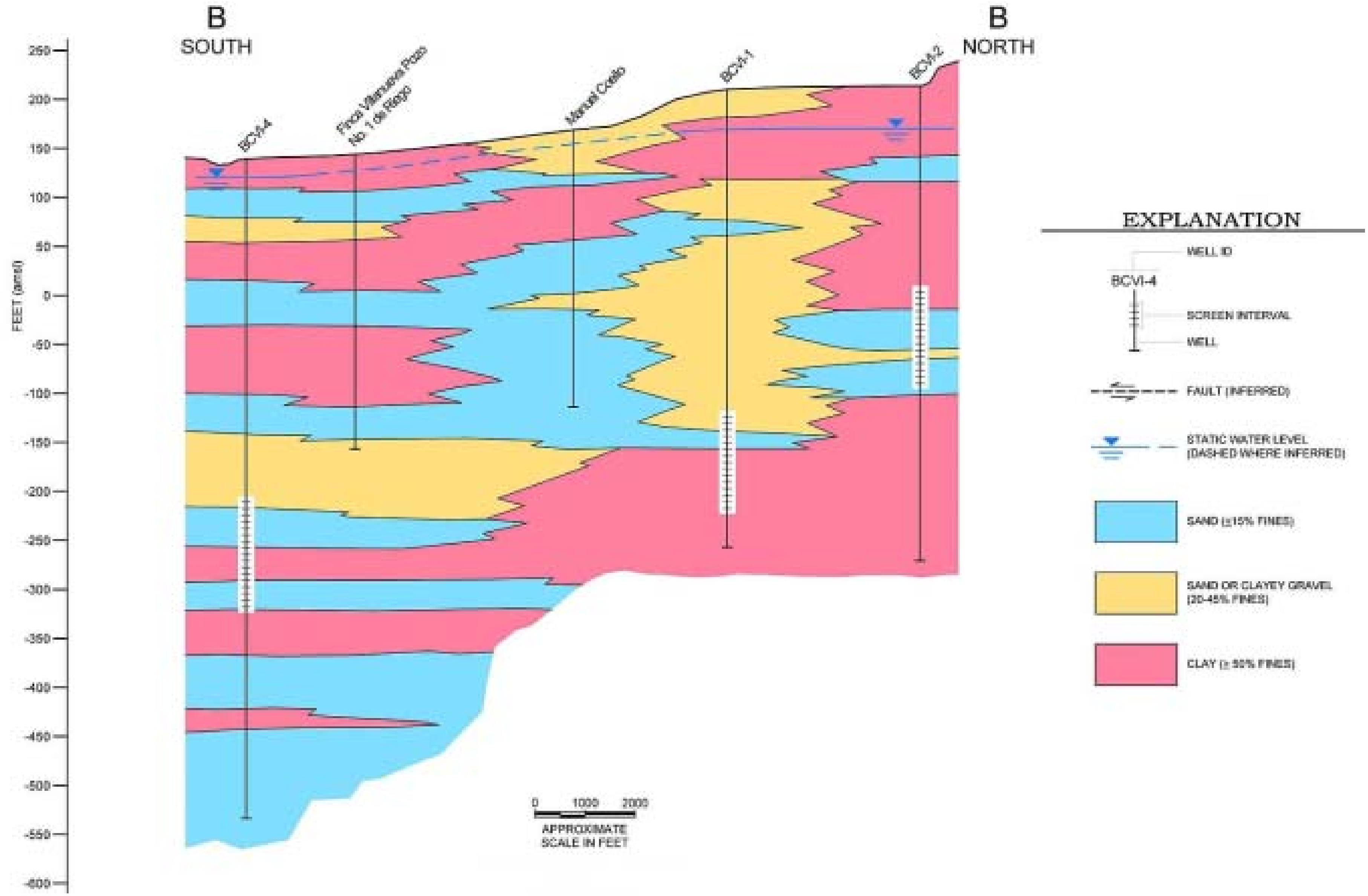
OTHER WELLS

1 Finca Villanueva Pozo No. 1 de Riego
2 Canteras No. 2
3 Pistala 1
4 Canteras No. 3
5 La Cuesta Campo de Pozo No. 1
6 Manuel Coello
7 Villa Linda Sur (8)
8 Gracias A Dios
9 La Victoria
10 Llanos de Canada
11 Rancho Chico Cocodrilos No. 2
12 Proasesa
13 Colonia Buena Vista
14 Guadalupe Lopez
15 Zip Villanueva 6
16 Tres Rosas
17 Colonia Municipal No. 1
18 Colonia Victoria
19 Villa Sol
20 Empacadora Gurise
21 Vivero Municipal
22 Orquidea No. 1
23 Colonia Suyapa
24 El Rastro Munic
25 Julio Solis
26 Independencia 1
27 Independencia 2
28 Roy Slocum
29 Villa Linda Norte
30 Orquidea No. 2

BROWN AND CALDWELL	DATE 2-22-02	SITE Villanueva, Republic of Honduras	FIGURE 4-1
	PROJECT 21143	TITLE Cross-Section Location Map	



BROWN AND CALDWELL	DATE 2-22-02	SITE Villanueva, Republic of Honduras	FIGURE 4-2
	PROJECT 21143	TITLE Cross Section A-A’	



BROWN AND CALDWELL	DATE 2-22-02	SITE Villanueva, Republic of Honduras	FIGURE 4-3
	PROJECT 21143	TITLE Cross Section B-B’	

4.2 Field Investigation Program

The field investigation conducted at Villanueva was tailored to locate sustainable groundwater supplies to accommodate the rapid growth of industry and residents in the area. Existing wells in the area demonstrate that the Ulua River alluvium and associated buried channel deposits are the primary aquifers for groundwater supplies. Previous studies indicate that appreciable groundwater yields of 6 to 32 lps (100 to 500 gpm) can be obtained from sand and gravel deposits at depth. However, the available information on the characterization and extent of these sands and gravel deposits is limited. The location of the wells within the valley suggests the possible presence of buried channels. If present, these channels would most likely be oriented along the axis of the valley in the vicinity of Villanueva. Thus, the objective of the field investigation was to explore potential water producing zones in the deeper channel ancestral river deposits. This included a preliminary characterization of these deposits, as well as determining water quality, aquifer transmissivities, specific yields, and yield sustainability for these lower zones.

In support of this objective, the field investigation consisted of the installation of three test wells and two observation wells at various areas in the Villanueva valley to characterize the buried channel deposits. Geophysical logging and pump tests for aquifer characterization were conducted and groundwater samples were collected at subsurface intervals identified as yielding sufficient groundwater supplies. This section summarizes the results of the field investigation. Appendix B describes the field investigation in greater detail.

4.2.1 Test Well and Monitor Well Installation Program. Three test wells (BCVI-1, BCVI-2, and BCVI-5) and two observation wells (BCVI-3 and BCVI-4) were installed as part of the Brown and Caldwell field investigation (Figure 4-1). Well BCVI-1 is located east of central Villanueva, along the Ferrocarril Nacional railroad track, approximately 350 m (1,148 ft) south of the road to San Manuel and La Lima. Wells BCVI-2 and BCVI-3 are located northeast of central Villanueva, approximately 200 m (656 ft) east of the Tela Company railroad track and approximately 850 m (2,789 ft) north of the road to San Manuel and La Lima. Well BCVI-3 was installed as a monitoring well for test well BCVI-2 and is located roughly 30 m (98 ft) northwest of BCVI-2. Wells BCVI-4 and BCVI-5 are located within the sugar cane plantation approximately 2 kilometers south of central Villanueva. The wells are approximately 75 m (246 ft) north of an ox bow lake associated with the Ulua River. Well BCVI-4 was installed as an observation well and is situated roughly 100 m (328 ft) south of the BCVI-5.

Test holes for wells BCVI-1, BCVI-2, and BCVI-4 were drilled to depths of 142, 146, and 207 m (465, 480, and 680 ft) below ground surface (bgs) respectively and are reportedly the deepest borehole penetrations in the area (Figure 4-4). These wells were installed to investigate potential water production zones associated with the ancestral river channel deposits in the area. A summary of well construction and completion details for each borehole is provided in Table 4-1.

Table 4-1. Summary of New Well Completion Details

Well	Borehole depth, bgs		Well depth, bgs		Screened interval, bgs		Function
	m	ft	m	ft	m	ft	
BCVI-1	142	465	137	448	101 - 134	330 – 438	test well
BCVI-2	146	480	94	310	65 - 91	212 – 300	test well
BCVI-3	104	340	97	317	72 - 94	237 – 307	observation well for BCVI-2
BCVI-4	207	680	143	470	107 - 140	352 – 460	observation well for BCVI-5
BCVI-5	146	480	142	466	66 - 142	216 – 466	test well

m = meter
ft = feet
bgs = below ground surface

After completion of each of the exploratory boreholes, geophysical logging was conducted. The geophysical logs included resistivity and spontaneous potential. Following logging, the boreholes were reamed to a larger diameter to accommodate the well installation. Drill cuttings and the geophysical logs were evaluated to determine the lithology encountered at each site. Lithologic logs, geophysical logs, and well construction details for wells BCVI-1, BCVI-2, BCVI-3, BCVI-4 and BCVI-5 are presented in Appendix B.

Figure 4-4. Reaming BCVI-5 to 24-inches

Figure 4-5. Constant Rate Discharge Test, BCVI-2

4.2.2 Aquifer Testing. Short- and long-term aquifer tests were performed on selected wells to evaluate the water resource development potential of the deeper river channel deposits. Short-term step-rate discharge tests were conducted on test wells BCVI-1, BCVI-2, and BCVI-5. Long-term constant-rate tests were conducted on test wells BCVI-2 (Figure 4-5) and BCVI-5. Due to excessive draw-down observed during the short-term test at BCVI-1, a long-term test was not conducted. BCVI-3 and BCVI-4 were utilized as observation wells during pumping of wells BCVI-2 and BCVI-5, respectively. Groundwater draw-down and recovery plots for all short- and long-term tests are presented in Appendix B. The aquifer tests show that the groundwater yields south of Villanueva in the area of BCVI-4 and BCVI-5 are the best. The area northeast of Villanueva, where BCVI-2 and BCVI-3 are located, provide lower groundwater yields.

4.2.3 Water Quality Survey. Groundwater samples were collected from each of the wells installed by Brown and Caldwell during this investigation (Figure 4-6). In addition, the following selected existing wells at Villanueva were included for water quality evaluation: Cañeras No. 2, Guadalupe Lopez, La Victoria, Manuel Coello, Pintala 1, Villa Linda Norte (1), and Villasol. Not all drinking water constituents were tested for in the sampled wells. The results of the water quality testing are summarized in Table 4-2 and presented in Appendix B.

Figure 4-6. Groundwater Sample Collection at Pintala 1

The municipal wells sampled were selected so as to provide a comprehensive understanding of the general water quality in Villanueva. Each of the wells sampled represent groundwater conditions in residential, agricultural and industrial areas, as well as publicly and privately installed facilities. The selection of wells also provides adequate spatial distribution so as to provide sufficient data to establish a water quality baseline for the community to build on in the future. Groundwater monitoring procedures are outlined in Appendix E of this report. Training in groundwater monitoring techniques was conducted for local staff as described in Appendix G.

Results for each of these constituents were compared to the Guidelines for Drinking Water Quality as published by the World Health Organization (WHO, 1996). It should be noted that while the Honduran government has not established country-specific guidelines for drinking-water quality, the Honduran Ministry of Health has accepted the guidelines established by WHO.

The results of the water quality survey show that the groundwater meets drinking water standards except as noted below:

1. One of the four test wells and five of the existing sampled wells had a presence of coliform. This indicates potential bacteriological contamination.

2. One of the four test wells and two of the seven existing sample wells had a presence of fecal coliform. This indicates bacteriological contamination of these wells.

3. One existing well (La Victoria) has a high iron level. The test result is unusually high, therefore, a resampling is recommended to confirm the test result. Iron is not a health risk, however, standards are defined for certain constituents such as iron because of customer complaints.

4. Arsenic was detected over the drinking water standard in one test well (BCVI-2) and one existing well (Guadalupe Lopez).

Table 4-2. Summary of Well Analytical Results

Analytical constituent	Drinking water standard[c]	Test wells				Existing wells[a]						
		BCVI-1	BCVI-2	BCVI-4	BCVI-5	Existing wells (range)	Guadalupe Lopez	La Victoria	Manuel Coello	Pintala I	Villa Linda Norte (I)	Villasol
General												
Acidity	mg/l[g]	37.97	36	36	--[d]	52-85	85[e]	74	78	62	73	52
Alkalinity	mg/l CaCO3[g]	339.27	383	284	--[d]	332-380	375[e]	370	380	342	362	357
Chloride	mg/l[g]	29	58.5	26	--[d]	23-69	69[e]	53	29	23	43	39
Conductivity	us/cm[g]	823	960	794	--[d]	632-915	890[e]	797	668	632	715	915
Hardness	mg/l CaCO3[g]	251	192	188	--[d]	196-388	196[e]	388	308	308	308	376
Iron	0.3[f] mg/l	0.09	0.03	<0.03	--[d]	<0.03-30.09	<0.03[e]	30.09	<0.03	<0.03	<0.03	<0.03
Manganese	0.5 mg/l (P)[f]	<0.03	<0.03	0.45	--[d]	<0.03	<0.03[e]	<0.03	<0.03	<0.03	<0.03	<0.03
Nitrate	50 mg/l	1.5	<0.01	0.11	--[d]	1.81-22.2	2.00[e]	19.84	5.00	6.00	1.81	22.2
pH	--[g]	--[d]	--[d]	--[d]	--[d]	7.00	7.00[e]	--[d]	--[d]	--[d]	--[d]	--[d]
Metals												
Arsenic	0.01 mg/l (P)[f]	0.00827	0.021	<0.005	<0.005	<0.005-0.0257	0.0257	<0.005	<0.005	<0.005	0.00694	<0.005
Zinc	3 mg/l	0.231	0.0745	<0.02	<0.02	<0.02-0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02
Bacteriology												
Total Coliform	UFC/100 ml	32	0	0	--[d]	0-48	0	48	1	11	11	40
Fecal Coliform	UFC/100 ml	2	0	0	--[d]	0-23	0	23	0	0	0	4
Radiochemistry												
Gross Alpha activity	5 pCi/L[h]	--[d]	9.1 pCi/L	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]
Gross Beta activity	50 pCi/L[h]	--[d]	10.8 pCi/L	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]
Pesticides	(range)[b] mg/l	None detected	None detected	--[d]	None detected	None detected	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]
Herbicides	(range)[b] mg/l	None detected	None detected	--[d]	None detected	None detected	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]
Volatile Organics	(range)[b] ug/l	None detected	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]

Source: SPL Houston Laboratory and Jordan lab Laboratorio de Analysis Industrial laboratory results. Test dates vary.
Note: Numbers in bold are those over the drinking water standard.
UFC – must not be detectable in any 100 ml sample.
[a] Existing wells that exceed drinking water standards.
[b] Drinking water standard varies by individual constituent.
[c] World Health Organization, 1996. Guidelines for Drinking Water Quality, 2nd ed. Vol 2 Health criteria and other supporting information and Addendum to Vol 2, 1998.
[d] Lab reports not available/not tested for this constituent.
[e] Two tests performed for this constituent, highest result shown.
[f] Levels likely to give rise to customer complaints.
[g] No drinking water standard.
[h] US standard.

4.3 Potential Contamination Sources

There are several potential sources of contamination to the alluvial aquifers in the vicinity of Villanueva, as described in this section. The local economy is supported by both agriculture and manufacturing at the large zoned industrial parks (ZIP) located north of the community. Sugar cane is grown in large fields south and east of the community. The fields are flood-irrigated from an aqueduct that channels water from the north part of the valley. It is suspected that any fertilizers, pesticides and herbicides that are not carried off with the unused irrigation water, percolate downward to the shallow groundwater, potentially contaminating groundwater supplies of the alluvial aquifer. Fortunately, analytical results from wells sampled in this area suggest that pesticide and herbicide groundwater contamination is currently not present in the agricultural areas of Villanueva.

Large-scale manufacturing at the ZIPs include clothing and related items. In addition, there is a large concrete cast plant that manufactures structural supports for buildings, roads and bridges, as well as a food processing plant located north of the municipal center that specializes in cooking oil. Although there is some treatment for both industrial and sanitary wastes in the industrial parks, most of the wastes are discharged to the ground surface, and may eventually flow into the Ulua River.

There are two gas stations that represent potential contamination sources. These gas stations have underground gasoline storage tanks. It is not known if these tanks are leaking.

Similarly, many of the existing and new residential areas possess inadequate sanitary facilities and most rely on latrines which discharge wastes directly to the ground. These sanitary wastes likely migrate to the shallow aquifer, contaminating groundwater with fecal coliform. Additionally, many of the existing residential wells in the area are screened to the surface, which provides direct vertical conduits for contaminants to migrate from the shallow subsurface to saturated zones below.

4.4 Numerical Simulation of Well Fields

A steady-state groundwater flow model was constructed for Villanueva as an interpretive tool to evaluate the groundwater resources available for the community. The groundwater flow model was constructed consistent with our understanding of existing hydrogeologic conditions. Recently collected and previously available information were incorporated into the Villanueva Valley aquifer system conceptual model, which was then used as a basis for the numerical model. The groundwater flow model is intended to evaluate the potential groundwater resources of the Villanueva Valley. A more detailed explanation of the model and results are presented in Appendix C.

Data collected during the field investigation as well as information from governmental sources were utilized in the construction of the Villanueva Valley groundwater model. The data that were utilized in model construction include:

- Stratigraphic information collected from test well borings and compiled from borehole logs of previously completed wells;
- Aquifer hydraulic property information calculated from aquifer testing in the recently completed test wells;
- Groundwater elevation data;
- Production well extraction rates;
- Production well completion records; and
- Annual average precipitation rates.

The conceptual groundwater budget indicates that of the estimated 270 lps (4,289 gpm) that enters the Villanueva Valley aquifers through mountain front and areal recharge, approximately 153 lps (2,427 gpm) is extracted by production wells and approximately 125 lps (1,983 gpm) flows to the Ulua River. This result suggests that the current estimated extraction rate could be increased to 271 lps (4,300 gpm) (a rate approximately equal to the estimated aquifer recharge total) on a long-term, continuous basis before groundwater discharge from the Villanueva Valley aquifer system to the Ulua River stops. At long-term production rates above the estimated aquifer recharge of 16,236 lpm (4,289 gpm), groundwater flow may be induced from the Ulua River and/or aquifer systems to the south of the Ulua River into the Villanueva Valley aquifer system. The model also suggests that it is possible to increase groundwater production to 372 lps (5,900 gpm), although changes in the groundwater flow system would occur.

Two predictive model simulations were performed to evaluate the potential effects of increased groundwater production on the Villanueva Valley aquifer system. Pumping rates were incrementally increased over the duration of the simulations. The first of these simulations uses hypothetical production wells located to the north of Villanueva, near the area of current population growth. The second of these simulations uses hypothetical production wells located to the south of Villanueva, near the existing high capacity cane field production wells.

For the north well field simulation, a total of 10 hypothetical production wells were included in the model in two rows extending northward from Villanueva, generally along the alignment of the railroad. Each well was assigned a pumping rate of approximately 24 lps (383 gpm). The simulation results indicate that the aquifer drawdown in the vicinity of the hypothetical wells located north of Villanueva would be approximately 12 m (39 ft) at the end of 20 years.

For the south well field simulation, a total of six hypothetical production wells were included in the model in two rows extending southward from Villanueva, just to the east of the existing cane field wells. Each well was assigned a pumping rate of approximately 38 lps (606 gpm). The simulation results indicate that the aquifer drawdown would be approximately 5 meters in the cane fields area at the end of the 20-year simulation period.

Due to the complexity of the geology and hydrogeology in the valley and the limited data available for the development of the groundwater flow model, the use of this groundwater model should be limited to developing a general understanding of potential groundwater resources in the valley. As additional geologic and hydrogeologic data are collected, the conceptual model and groundwater flow model can be updated, thereby increasing the effectiveness of the groundwater flow model as a tool to sustainably manage the valley's groundwater resources.

The following points identify some of the information that should be collected or improved in order to increase the accuracy of the groundwater model and thus increase its future effectiveness as a groundwater management tool:

- Groundwater surface elevation and flow direction. Additional groundwater elevation data for the areas outside the immediate vicinity of Villanueva should be collected to better characterize the groundwater flow directions in the Villanueva Valley.

- Groundwater extraction rates. Groundwater extraction from the Villanueva Valley aquifer system constitutes a substantial portion of the aquifer system water budget, and improving the estimates of groundwater extraction will greatly improve the assessment of the impacts of pumping on the aquifer system. The installation of well production meters is suggested.

- Elevation of the Ulua River. The Ulua River is assumed to act as a constant head boundary for the Villanueva Valley aquifer system, and an accurate measurement of the elevation will improve the model calibration and decrease the uncertainty in the conceptual groundwater budget.

- Vertical definition of the Villanueva Valley aquifer system. A better understanding of potential confining units in the aquifer system will allow for an assessment of the possible downward migration of near-surface groundwater toward wells screened in deeper portions of the aquifer system. As additional wells are drilled, the added well log information should be collected and evaluated.

4.5 Aquifers and Recommended Well Field

On the basis of the results of the conceptual model, the field investigation, and the numeric simulation of groundwater flow, the following sections outline the interpretation of available aquifers and recommended well fields.

4.5.1 Groundwater Quality. Based on the groundwater analytical results, the best quality groundwater is located generally south of Villanueva, in the vicinity of the sugar cane fields. North and northeast of the community, the groundwater contains higher levels of dissolved solids such as calcium and chloride. These levels decrease gradually to the south, towards the Ulua River. Also, elevated concentrations of coliform and nitrate were observed in wells within the central part of the community, specifically in the vicinity of well La Victoria, and to the north, at well Villa Sol. Elevated nitrate concentrations were also reported at well Caneras No. 2. At well BCVI-4, no coliform concentrations were reported and concentrations of nitrate were detected just above laboratory reporting limits. Also, levels of select dissolved solids (sodium, potassium and magnesium) at BCVI-4 were reported at lower concentrations than those reported in wells in the northeast part of the Villanueva Valley.

4.5.2 Aquifer Characteristics. This study focused on the exploration of the deeper sand and gravel river deposits of the Villanueva Valley as potential water production zones for the community. The results from this investigation indicated that laterally extensive sand and gravel deposits at depth are present, but not as a continuous lithologic unit along the longitudinal axis of the valley. Instead, the sands and gravels are present as discontinuous beds and lenses, and grade into finer-grained sands and silts. Also, within the Villanueva Valley, the lithology and aquifer characteristics of these deeper units are interpreted to vary from west to east, and from north to south

The alluvial materials along the eastern boundary of Villanueva, along the western flanks of the Siren Mountains, are characterized as generally containing a greater percentage of silt and clay. Drill cuttings examined from well BCVI-I indicate interbedded deposits of gravel, sand, silt, and clay. Sandy-clay was encountered from approximately 134 m (440 ft) to the total depth of the borehole at 142 m (465 ft) bgs. Aquifer test results from BCVI-1 and existing wells indicate poor production yields from wells in this area. Conversely, the lithology along the western boundary of the municipality, in the vicinity of Las Caneras is characterized as clean sands and gravels, of greater permeability than those to the east. Existing wells to the west, installed at comparable depths show greater higher production rates (Las Caneras No. 2 at 2,271 lpm (600 gpm), Pintala No. 2 at 1,703 lpm (450 gpm)) than wells to the east screened at comparable depths (Villa Linda Norte – 151 lpm (40 gpm), Gracias a Dios – 208 lpm (55 gpm)).

Early investigations conducted by SANAA and the British Geological Survey demonstrated the area to the south of Villanueva offered the best prospects for developing a well field of high production, especially towards the west, within the alluvium along the eastern flanks of the Merendon Mountains. Based on the information from the Brown and Caldwell field investigation, the thickness of sand and gravel units along the western and southern portions of the valley is interpreted to be greater and extend laterally for a greater distance than those to the north. From west to east, the lithology generally grades to finer-grained sediments. Based on inspection of existing boring logs and lithologic logs from this investigation, the deeper lithologic units along the eastern and northern portions of the valley are characterized clay and clayey sands and gravels.

The portion of the Villanueva Valley with the highest potential for future groundwater production is located generally south of the City of Villanueva, in the vicinity of the sugar cane fields and further south toward the Ulua River. The aquifer system is this portion of the valley, which is occupied by the Ulua River sediments, has the highest transmissivities, and the production capabilities of the existing wells exceeds that of wells located in other portions of the aquifer system.

5.0 WATER RESOURCES MANAGEMENT SYSTEM

The Water Resources Management System (WRMS) is a desktop computer application developed to store, manage, and analyze technical information gathered and generated for this project. The application is a management tool that can be used by the municipalities and other decision-makers to support sustainable management of their groundwater resources. The system is composed of both a data management system and a geographic information system (GIS) linked together as one application. Through the WRMS, users can:

- manage and generate reports for wells, storage tanks, and springs;
- view well logs and well completion diagrams;
- analyze water quality and water level data;
- track statistics on water use; and
- view wells, water quality information, and aquifer characteristics on maps of the study area.

The WRMS is considered an important component in our water resource management plan. The system is briefly described in this section and is described in more detail in the Water Resources Management System Users Guide (Appendix D). The application consists of two primary components; a data management system and a GIS. The application is written so that the two components work together and function as one system. Data are shared back and fourth between the data management system and the GIS.

The data management system used is Microsoft Access, which is a relational database designed to efficiently manage complex data. The data are stored in a series of tables. Each table stores a different type of information, and each table is linked to others by a key field that defines the relationship. For example, one table contains a record of each well, while another table contains all the water level measurements. The table containing the water levels also contains the name of each well so that it can be linked back to the appropriate well in the well table. This way, detailed information on each well and water level measurements can be stored most efficiently, without the need to maintain the same piece of information more than once, which would potentially introduce erroneous data into the system.

The GIS used is ArcView®, by Environmental Science Research Institute. A GIS is an electronic mapping and analysis system. The power of GIS lies in its ability to manipulate, display, and analyze information on a map by linking map elements to attribute data in a database. For example, a well whose location is identified as a dot on the map is connected to the construction data, sampling results, and water level information in the database. The user can post any of this information as text on the map, choose specific symbols or colors to represent these data, and overlay this layer of information on other map features. Because the data management system and GIS work together, it provides the user with a powerful set of management and analysis tools.

Both of these components are linked through a common interface developed in Microsoft Visual Basic. The interface is a series of screens that guide the user through various application functions. Through the interface, the user can enter or update data, view reports, generate graphs, display scanned images, and create customized maps. The interface can be displayed in English or Spanish, uses water resource terminology, and is designed to be user-friendly. Through this interface, municipalities will be able to continue to update their water resource data and use it for decision-making in the future.

5.1 Benefits of the WRMS

The WRMS consolidates, perhaps for the first time, the most critical water resource information for a municipality. It provides a central place to manage, analyze, and display water resource information in both map and tabular form. The WRMS accommodates all major types of information needed for sound water resource management including data on wells and other water sources, future demand and growth, infrastructure and organizational boundaries, and water quality and aquifer characteristics.

Because the system is designed to accommodate additional data as more information is collected and wells are created or modified in the future, it can be used to facilitate sound water resource decision-making in the future. It is easy to use and requires minimal training, which will facilitate continued system use. It uses a standard methodology for identifying and prioritizing future well sites, which will allow municipalities to continue to apply a consistent planning approach.

5.2 Use and Management

The WRMS is designed to work in conjunction with the findings of this report. Most of the data collected or developed for the report are contained in system, and are available for continued analysis, display, and incorporation with new data as it is collected. The system can be used to view and explore additional details of the existing water system.

The WRMS should be used to provide a common environment for communication among stakeholder agencies for water resource planning. The system provides a consistent view and methodology for analyzing water resource data. Consistently using it as a communication tool among stake-holders will make the sometimes confusing and complex technical information easier to understand. New data, such as new wells, additional sampling results, or new water level measurements should be entered into the system on a regular basis (annually) in order to have the most up-to-date information available for decision-making.

5.3 Villanueva Data

Table 5-1 summarizes mapping information collected on Villanueva. This data is included for review in the WRMS. There are 70 wells with information collected. Ten wells, BC-VI1, BC-VI2, BC-VI4, Cañeras No. 2, Guadalupe Lopez, La Victoria, Manuel Coello, Pintala I, Villa Linda Norte (I), and Villasol, have water quality information in the WRMS.

A compact disk containing the WRMS and all of the Villanueva data described above is included with this report.

Table 5-1. Villanueva GIS Data Dictionary

File name	File type	Description	Date	Source	Scale of source data
Cad-villa-bndry.shp	shape	Outlines of industrial, agricultural, rural and urban perimeters		CAD	
Cad-villa-ruralbndry.shp	shape	Polygon of rural perimeter		CAD	
Cad-villa-adbndry.shp	shape	Polygon of agricultural perimeter		CAD	
Cad-villa-industriabndry.shp	shape	Polygon of industrial perimeter		CAD	
Cad-villa-urbanbndry.shp	shape	Polygon of urban perimeter		CAD	
Cad-villa-urbbndry.shp	shape	Outline of urban perimeter		CAD	
Cad-villa-munibndry.shp	shape	Outline of municipal boundary.		CAD	
Cad-villa-munibndrypoly.shp	shape	Polygon of municipal boundary.		CAD	
Cad-villa-pipe.shp	shape	3-inch, 4-inch, 6-inch, and 8-inch pipelines, pvc			
Cad-villa-neighbor.shp	shape	Outline of neighborhoods			
Bc-villa-springs.shp	shape	Point location of one spring in Villanueva. This point is not surveyed, location estimated based on topographic map.		BC	
Villa-railroad.shp	shape	Line of railroad, traced off of topographic map		Topographic map	
Villanueva-rivers.shp	shape	Lines of rivers – using Cad and Topographic map		CAD, Topographic map	
Cad-villa-streets.shp	shape	Streets of Villanueva.		CAD	
Topo-villa-urb-90.shp	shape	Urban developed areas based on the 1990 topographic map of Villanueva.	1990	Topographic Map	
Aerial-villa-urb-00.shp	shape	Urban developed areas based on the 2000 aerial photograph of Villanueva	March 2000	USGS Aerial Photograph	1:40,000
Villanueva 1990.img	image	Villanueva scanned in topographic map aligned to NAD 27. – does not cover outlying areas.	1990	Topographic Map Instituto Geografico Nacional, Tegucigalpa, D.C., Honduras	
Villanueva aerial2000.img	image	Aerial photo of Villanueva aligned to NAD 27.	March 2000	USGS Aerial Photograph	1:40,000
Villa&Lima_utm.tif	image	Topographic map scanned in and aligned to NAD 27.		Topographic Map	
Villa-vect-1of4.shp	shape	Vector contour file purchased from Intec America. 1 of 4 vector contour files for Villanueva		Intec America	30 meter, one arc second
Villa-vect-2of4.shp	shape	Vector contour file purchased from Intec America. 2 of 4 vector contour files for Villanueva		Intec America	30 meter, one arc second
Villa-vect-3of4.shp	shape	Vector contour file purchased from Intec America. 3 of 4 vector contour files for Villanueva		Intec America	30 meter, one arc second
Villalalima-4of4.shp	shape	Vector contour file purchased from Intec America. 4 of 4 vector contour files for Villanueva, also serves as vector contour file for La Lima area.		Intec America	30 meter, one arc second

6.0 RECOMMENDED GROUNDWATER RESOURCES MANAGEMENT PLAN

This chapter presents recommendations to ensure water supply sustainability. Recommendations for groundwater management, wells, groundwater monitoring, wellhead and recharge area protection, water utility management, and water supply are presented.

6.1 Groundwater Management

Considering the growing use of groundwater in the Sula Valley, control should be kept to protect the groundwater resource, including control of excessive aquifer water level declines and control of potential contamination sources. Due to financial and technical limitations at each municipality in the Sula Valley and surrounding areas, it is recommended that joint efforts be initiated to create a groundwater management agency. This agency would provide technical advice, keep records of aquifer behavior, and maintain the hydrogeological database. As the private sector of the Sula Valley depends on groundwater for commercial, industrial, and agricultural purposes, it is recommended to develop an agency with a board of directors formed by representatives of the municipalities and private organizations, such as the Chamber of Commerce. This model of institution would give assurance that the agency would maintain independence and stay free of periodic staff changes.

Considering the need to start properly managing the main watershed basins that contribute to the Sula Valley as part of a flood mitigation project, a general plan to protect aquifers would be complementary.

6.2 Drilling Plan

The following recommendations are made regarding drilling of future wells:

1. Drill the future production wells in the southern area of Villanueva. Test well BCVI-5 is suitable to be converted to a production well.
2. Drill a well approximately every three years until a total of six have been completed by the year 2020. This assumes a well capacity of 38 lps to 44 lps (600 gpm to 700 gpm) each.
3. Acquire in advance the land needed to construct production wells. A well site with a size of approximately 30 m by 30 m (100 ft by 100 ft) is recommended.
4. The wells should have a depth of approximately 122 m (400 ft) to take advantage of the three aquifer strata identified below a depth of 67 m (220 ft).
5. The production wells need to have a sanitary seal with a minimum length of 15 m (50 ft).
6. The diameter of the well casings need to be adequate to install a pump with a capacity sufficient to supply the 38 lps to 44 lps (600 gpm to 700 gpm) and lift the water to the water tanks. The estimated well diameter is in the range of 356 mm to 406 mm (14 to 16 in).
7. It is recommended that the wells be equipped with water lubed vertical turbine pumps.
8. Each production well should be equipped with the equipment necessary to disinfect the water, monitor the groundwater level, quality, and production quantity.
9. In the lowest area of the valley, near the Ulua River, construct well flood protection pedestals with a height on the order of 2 m (6 ft).

6.3 Groundwater Monitoring

An important component of managing the current water supply in Villanueva and ensuring compliance with drinking water standards is the development and maintenance of a regular groundwater monitoring program. A regular monitoring program will ensure compliance with drinking water standards and will provide a useful tool for tracking groundwater quality, groundwater levels, and usage, as well as help with growth planning in the future.

There are several components that contribute to a successful monitoring program, each of which are equally important. These components include groundwater level data collection, groundwater production data collection, water sample collection, analysis of water samples and review, and compilation and understanding of water chemistry results. Each of these components is necessary in order to maintain a successful groundwater monitoring program. Information regarding the steps necessary to complete a monitoring program are outlined in the Groundwater Level and Monitoring Program, Field Manual, December 2001, included as Appendix E. This document was distributed to various members of the municipality during the groundwater level and monitoring training provided by Brown and Caldwell in December 2001.

The following recommendations are made regarding groundwater monitoring:

1. The monitoring of the wells should be continued at a three-month frequency.
2. The well monitoring should consist of monitoring and recording the groundwater level and the quantity and quality of the water.
3. It is recommended that the well monitoring network consist of 15 wells, as listed in Appendix E.
4. The collected monitoring information should be recorded in the computer database.

6.4 Wellhead Protection

An important component in protecting the groundwater quality used for public water supply in Villanueva is establishing a wellhead protection program. Wellhead protection is the practice of managing the land area around a well to prevent groundwater contamination. Prevention of groundwater contamination is essential to maintain a safe drinking water supply.

Development of a wellhead protection plan for Villanueva consists of five key steps that are described in Appendix F. To implement a management plan to protect the well capture areas and the general aquifer recharge areas it is recommended that municipal control be established for the following items:

1. Discharge of municipal wastewater.
2. Discharge of industrial wastewater.
3. Disposition of solid waste.
4. Storage and distribution of hydrocarbon products.
5. Storage and distribution of chemical products (agricultural and industrial).

6.5 Water Resource Management System

Brown and Caldwell developed a Water Resources Management System to store, manage, and analyze water resource related data gathered and generated for this project, and for data to be collected in the future by municipality. The following recommendations are made regarding the Water Resource Management System:

1. The database should be regularly updated by the municipality by adding groundwater level, groundwater production, and water quality data for the wells in the monitoring network.
2. Routinely use the database to input information regarding new wells, well monitoring information, and general water system operation data.

6.6 Water Utility Management

An important aspect of ensuring a sustainable water supply is having a functioning water utility with the proper organizational structure. The water utility is responsible for properly managing, operating, and maintaining the water system, and must be financially self-sufficient. Several water utility management recommendations are listed below.

1. Continue to maintain a complete list of all water system customers that includes descriptive information for each customer. This information should include name, address, service line size, and type of customer (residential, commercial, etc.).
2. Update the financial plan for the water utility that establishes budget needs and defines an equitable rate and new connection fee structure that is adequate to cover the costs of expanding, operating, and maintaining the water system. Continue to ensure that users are routinely charged for and pay for water supply.
3. Have adequate staff that is trained on a regular basis to address operational and maintenance needs.
4. Investigate possible sources of grant and loan financing to help improve and expand the water system.

6.7 Control Over Well Construction

It is recommended that control over the construction of wells by others be established through municipal regulation. The objectives are to ensure that wells constructed by other parties meet appropriate construction standards and that information obtained during well construction is recorded and placed in the database.

6.8 Control of Water Losses

A program should be developed to detect and eliminate leaks in the water distribution system. The first step is to conduct a study to define the amount of water loss and recommend the best areas for leak repair and/or main replacement. A water conservation program should be initiated to ensure that customers are using water efficiently.

6.9 Water Quality

The wells should be disinfected with chlorine. For the several wells with a detected presence of total coliform and fecal coliform, it is recommended that they be immediately disinfected followed by a new water quality analysis after the chlorine level is reduced back down to zero. This will determine if the contamination is still entering the well. If the well still has coliform or fecal coliform, consider other measures, including permanent disinfection, identification and elimination of the contamination source, and well closure.

6.10 Water System Expansion Plan

The preparation of a water system expansion plan is recommended. The municipality is responsible for the water supply system. Therefore, the municipality must ensure that the public or private investment for the water system expansion is properly planned. Several objectives are recommended.

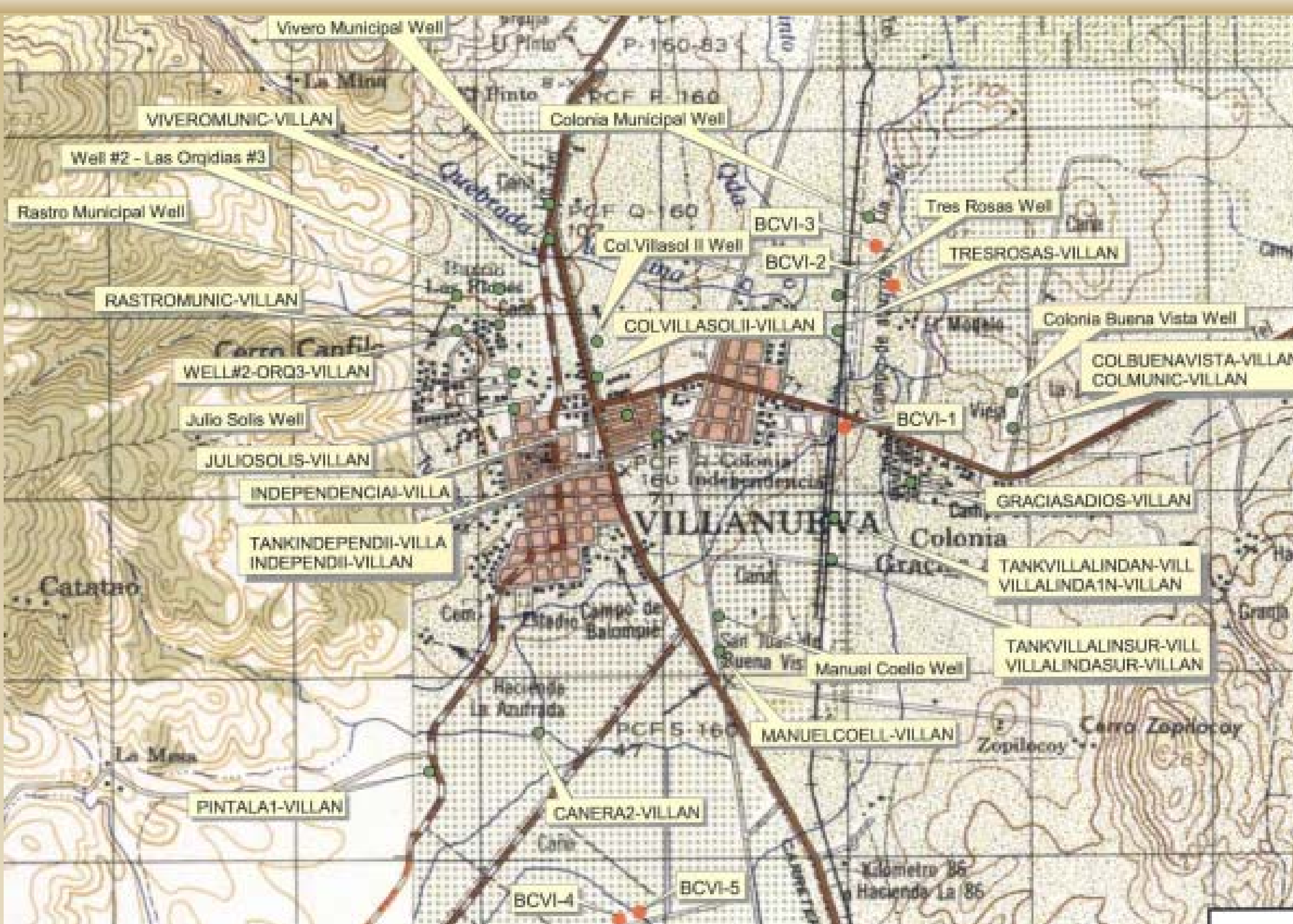
1. Reduce the total number of production wells by planning fewer, larger capacity wells in the south area.
2. Operate more efficient wells with a greater specific yield.
3. Plan for the construction of new wells, pumping lines, and storage tanks to serve all sectors of the city.
4. Investors who wish to start new development projects should receive water from the municipal water system after paying the appropriate connection fees.

APPENDIX A

Conceptual Model and Rationale for Phase II Field Investigation

CONCEPTUAL MODEL AND RATIONALE FOR PHASE II FIELD INVESTIGATION

Muncipality of Villanueva, Republic of Honduras, C. A.



July 2001

Sub-Consultant:

ATICA, S. de R. L.
Asesores Técnicos en Ingeniería y Ciencias Ambientales

USAID

Consultant:

BROWN AND CALDWELL
Environmental Engineering and Consulting

INTRODUCTION

This document represents the hydrogeological conceptual model for the Villanueva area and the rationale for the conduct of the Phase II field investigation studies. The project background, available water resources and needs, hydrological setting, data gaps, and recommended areas for field investigation and activities are described below.

BACKGROUND

The purpose of this project is to develop a water resources management plan for the Municipality of Villanueva which addresses a sustainable municipal water supply. This project is funded by the United States Agency for International Development (USAID).

Villanueva is located approximately 39 kilometers south of San Pedro Sula in the Province of Cortes. Population, water consumption, and water production data flow rate is not available at this time, however, this information is being gathered under Phase I. This information will be presented in the final report. Villanueva operates several rural water systems that are located several kilometers to the north and west. These rural water systems are not addressed by this project. Villanueva currently relies on groundwater for the majority of its water supply. It is anticipated that reliance on groundwater for municipal water supply will increase as population growth continues in the future.

EXISTING WATER RESOURCES

Villanueva relies almost completely on groundwater for its water supply. Two spring sources provide the remainder of the water supply.

Villanueva uses approximately 17 wells located within and around Villanueva for its municipal water supply. The combined capacity of Villanueva's wells is approximately 1,500 gallons per minute (gpm). The wells range in depth from 105 to 400 feet. No centralized or well head treatment is provided. The major source of water for Villanueva are three wells that are located within a sugar cane plantation area south of Villanueva. These wells were constructed in 1998 and 1999. The average pumping rate for each of the three wells is approximately 600 gpm. The remaining wells are relatively small and have pumping rates ranging from 30 to 400 gpm. In addition, several other industrial and agricultural wells are located within the region.

The water distribution system consists of two pressure zones and multiple water storage reservoirs. The majority of the customers are located in the lower pressure zone. The upper pressure zone serves customers located in the higher elevation areas on the west side of Villanueva.

Water is pumped directly from the three sugar cane wells to a mid-level reservoir located west of the central part of Villanueva. From this reservoir, water flows by gravity to supply the residents in the higher elevations of Villanueva. Water is also pumped from a second reservoir at this mid-level location to an upper water storage reservoir. Water flows by gravity to serve the hillside residents within Pressure Zone II. The other wells pump directly into the lower pressure zone of the distribution system or into elevated storage tanks distributed throughout the system.

A majority of the water piping system consists of a looped network of 2-, 3-, and 4-inch water lines. The amount of water lost through the distribution system is not known.

FUTURE WATER NEEDS

Villanueva has experienced rapid growth in recent years. Several recently constructed industrial parks have resulted in increased residential water supply demand. Villanueva expects that most future growth will occur to the east and northeast. No population projections are available but are being gathered at this time. This information will be included in the final report.

Since most of the wells lack totalizing production meters and individual residences are not metered, the amount of water used by Villanueva cannot be precisely calculated. However, this information is being gathered by using a portable flow meter that was purchased for this project. The meter will be attached to the discharge side of the well and the flow of the well recorded on a weekly basis. The results will be presented in the final report.

RATIONALE FOR WATER RESOURCE EXPANSION

The objective of this project was to locate sustainable groundwater supplies that could be utilized in a cost effective manner. The optimal groundwater supply is close to existing water system infrastructure, has acceptable water quality and a yield that meets anticipated supply needs.

GEOLOGICAL SETTING

Villanueva is located on the western flanks of the Sula Valley. Geologically, the low lying areas of the Sula Valley floor are characterized by Quaternary Valle de Sula alluvial deposits, with valley walls comprised of Jurassic Cacaguapa Schists to the east and west, and the Tertiary Matagalpa Formation and Padre Miguel Group and Cretaceous Yojoa Group to the south and southeast. The Sula Valley drains into the Caribbean Sea to the north. Generally, this area receives between 55 and 85 inches of precipitation per year. Additional rain gauging and climatical stations were not necessary to successfully complete this study.

Villanueva is located within an alluvial valley, located on the western flanks of the Sula Valley. The valley was formed by faulting of the surrounding uplands. These upland areas are comprised of limestones of the Yojoa Group. The major faults are oriented along a north-northeast trend along the front of the upland. No faulting has been observed or reported within the Villanueva alluvial valley (see Figure 1).

The axis of the Villanueva alluvial valley parallels the north-northeast fault system. The valley is approximately 10 kilometers in length and ranges from approximately 2 to 4 kilometers in width. The valley is bordered on the south by the Ulua River and bordered on the east and west by the limestone uplands. The alluvial materials can be subdivided into two depositional settings: the Ulua River alluvium and the suspected buried channel deposits that comprise the Valley margin alluvium (see Figure 1).

The Ulua River alluvium extends from the southern edge of the Villanueva city limits to the Ulua River. These materials are comprised of channel and flood plain deposits of the Ulua River. Boring logs completed within the Ulua River alluvium indicated that the upper 250 feet of alluvial materials are characterized as a fining-upward sequence (see Figure 2). The upper 10 to 20 feet of alluvial materials are characterized as inter-bedded clayey-silts and silts. These materials grade into inter-bedded silts and fine- to medium-grained sands from approximately 20 to 100 feet. Below 100 feet, approximately 150 feet of inter-bedded fine-, medium-, to course-grained sands and gravels have been observed. A laterally extensive clay unit has been observed at a depth of approximately 250 feet. This clay is estimated to be approximately 35 feet thick. Below the clay unit, additional sands and clays have been observed, however, available data is limited.

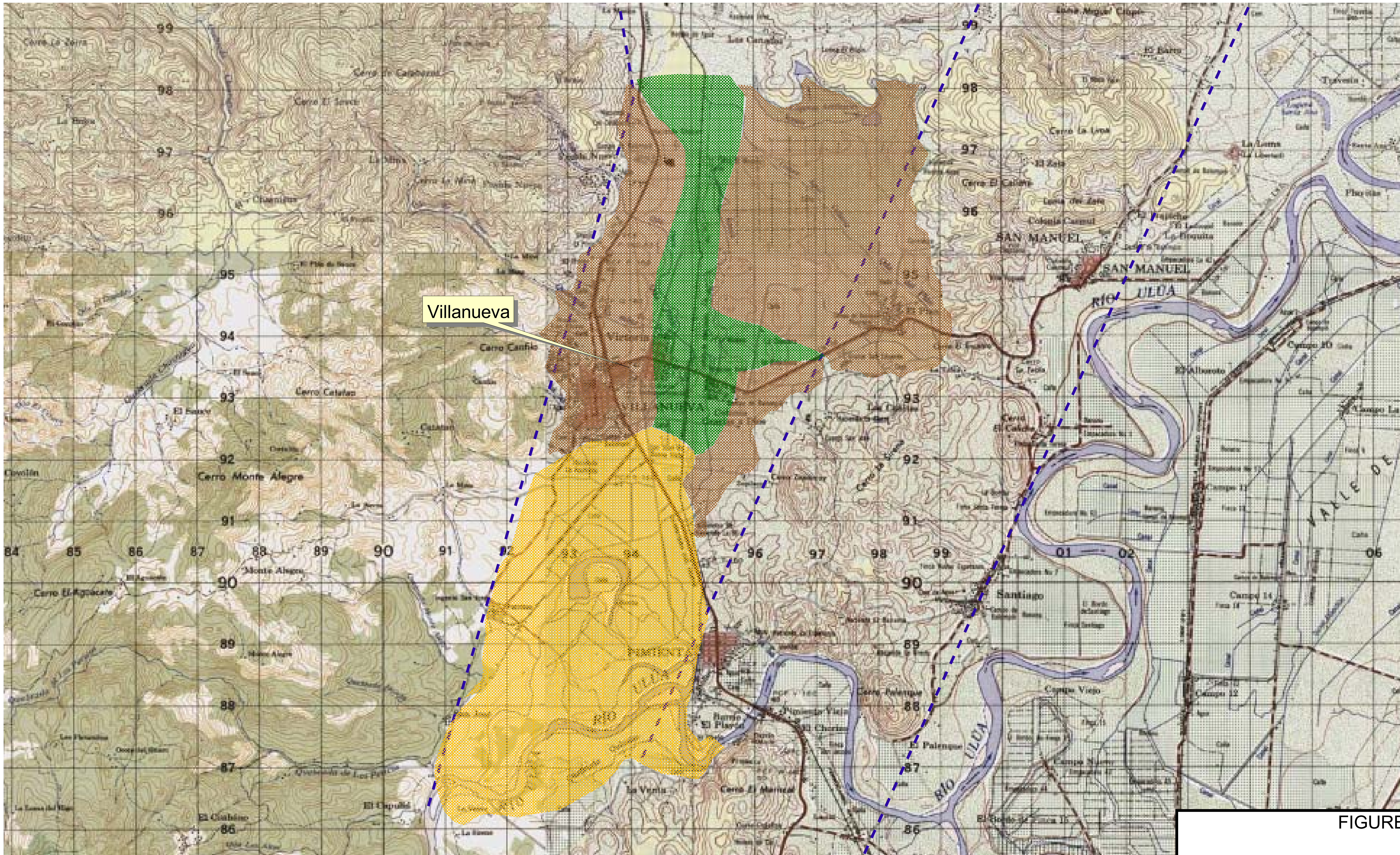
The estimated extent of the valley margin deposits is presented in Figure 1 and Figure 3. The valley margin deposits are generally characterized as alluvial fan and mudflow deposits that were derived from erosion of the surrounding uplands. These deposits are generally characterized as heterogeneous inter-bedded clays, silts, sand, and gravel.

Wells constructed in the central portion of the valley margin deposits (along the axis of the valley), indicated that appreciable groundwater yields (100 to 500 gpm) can be obtained from sand and gravel deposits at depth. The available information on the characterization and extent of these sands and gravel deposits is limited. However, the location of the wells within the valley suggests the possible presence of buried channels. These channels would most likely be oriented along the axis of the valley (see Figure 1).

Vegetation and land use maps are not included in this report as they are not considered appropriate at this time.

HYDROGEOLOGICAL SETTING

The Villanueva Valley is bounded to the east and west by upland areas comprised of Yojoa Group limestone. These upland areas serve as the major surface and groundwater recharge areas for the alluvial materials of the valley. Surface water infiltrates into the fracture and conduit networks of the uplands providing groundwater recharge to the valley bedrock and alluvial materials. Groundwater from the western uplands generally flows to the east, and groundwater from the eastern upland areas generally flows to the west. Once the groundwater from the upland areas enters the valley alluvium, groundwater flow will generally begin to move down the valley and towards the Ulua River, which serves as the major groundwater discharge points for the valley hydrologic system.



N

1 0 1 2 Kilometers

RIO ULUA ALLUVIUM (HIGH POTENTIAL GROUNDWATER YIELDS)

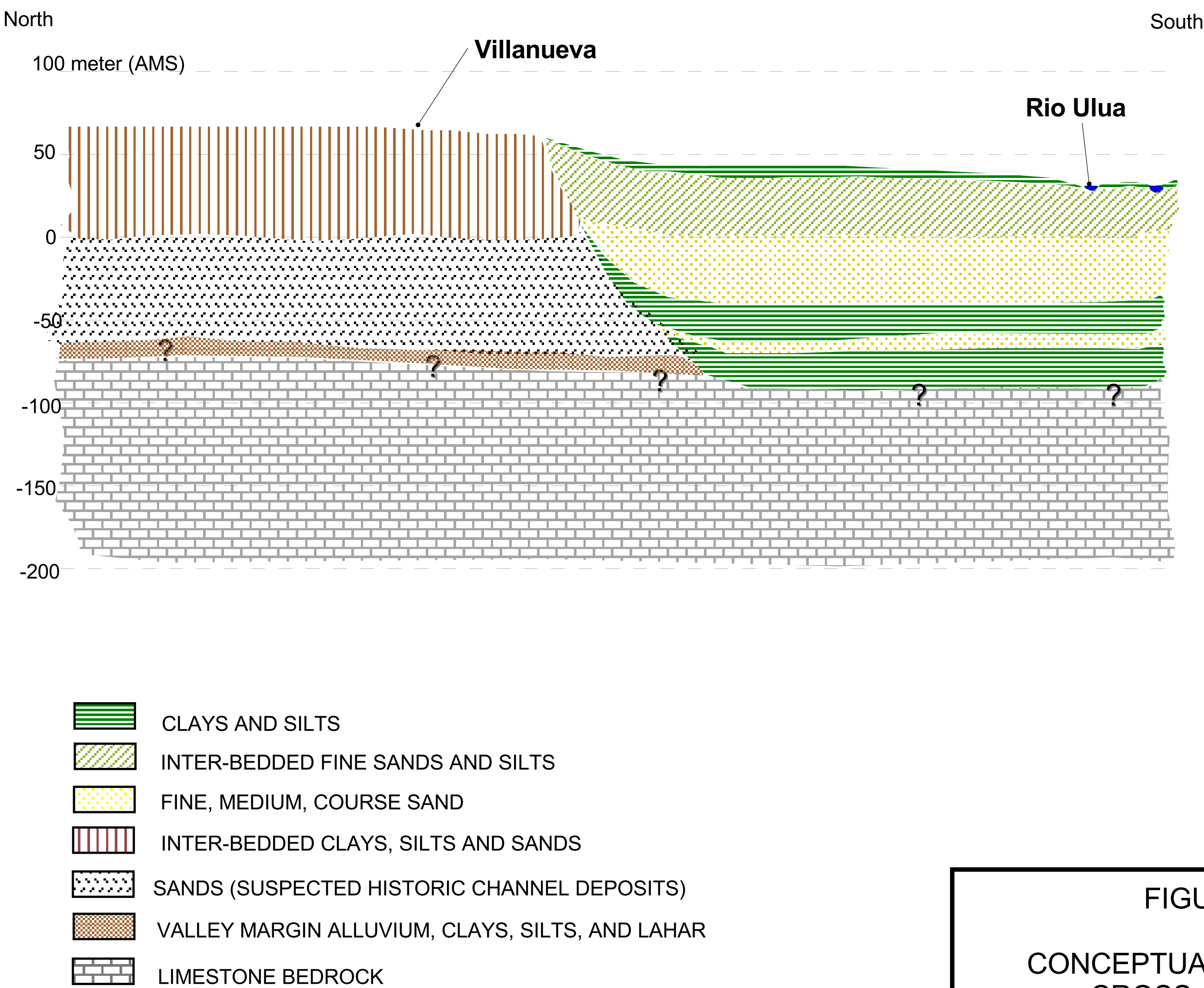
SUSPECTED BURIED CHANALS (MODERATE POTENTIAL GROUNDWATER YIELDS)

VALLEY MARGIN ALLUVIUM (LOW POTENTIAL GROUNDWATER YEILDS)

FAULTS

FIGURE 1

CONCEPTUAL GEOLOGY
OF THE
VILLANUEVA VALLEY

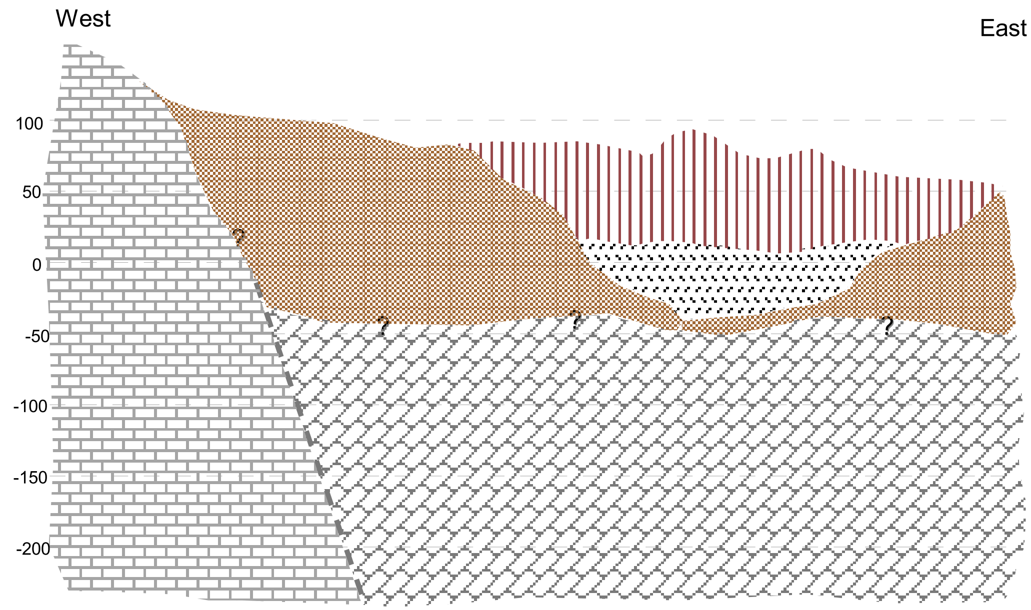


Drawing not to scale.

FIGURE 2

CONCEPTUAL GEOLOGIC CROSS-SECTION

VILLANUEVA



INTER-BEDDED CLAYS, SILTS AND SANDS

SANDS (SUSPECTED HISTORIC CHANNEL DEPOSITS)

VALLEY MARGIN ALLUVIUM, CLAYS, SILTS, AND LAHAR

LIMESTONE BEDROCK

Drawing not to scale.

FIGURE 3

CONCEPTUAL GEOLOGIC CROSS-SECTION

VILLANUEVA

Groundwater occurs within the valley margin alluvium, the suspected buried channel deposits, and the Ulua River alluvium. Based on review of the available well information, aquifers within the valley margin deposits are limited in nature and are unable to produce sufficient supplies of groundwater. Currently, 11 wells are screened within the valley margin (see Figure 4). Groundwater production from these wells range from 30 to 100 gpm, with an average yield of 57 gpm. This is a consistent trend observed throughout the valley margin deposits.

Six wells are suspected to be screened within the buried channel deposits (see Figure 4). Groundwater production from these wells range from approximately 50 to 500 gpm with an average yield of approximately 190 gpm. The available information on the buried channel aquifer is limited, resulting in the need for additional information to characterize the lateral extent of the aquifer system. It is believed that these aquifers are linear in nature and may extend along the axis of the valley.

The Ulua River alluvium presents the greatest potential for producing sustainable yields. Currently, four municipal wells (see Figure 4) are screened within the sand and gravel aquifer that occurs between 100 and 250 feet in depth. Groundwater production from these wells range from 200 to 600 gpm with an average yield of 390 gpm. Additionally, there are unconfirmed reports of irrigation wells screened within the Ulua River alluvium that produce in excess of 1,000 gpm.

RECOMMENDED AREAS FOR FIELD INVESTIGATION

Based on a review of the available data for Villanueva, the Ulua River alluvium and the suspected buried channel aquifers have been identified as having the highest probability of providing sustainable groundwater supplies. As a result, it is recommended that the Ulua River alluvium and suspected buried channel aquifers be further investigated.

DATA GAPS

The Phase I data collection and evaluation has identified the following data gaps:

- Additional information is required to evaluate the Ulua River alluvium for sustainable yields of groundwater; and
- additional information is required to evaluate the suspected buried channel aquifer deposits to determine the extent and sustainable yields of groundwater.

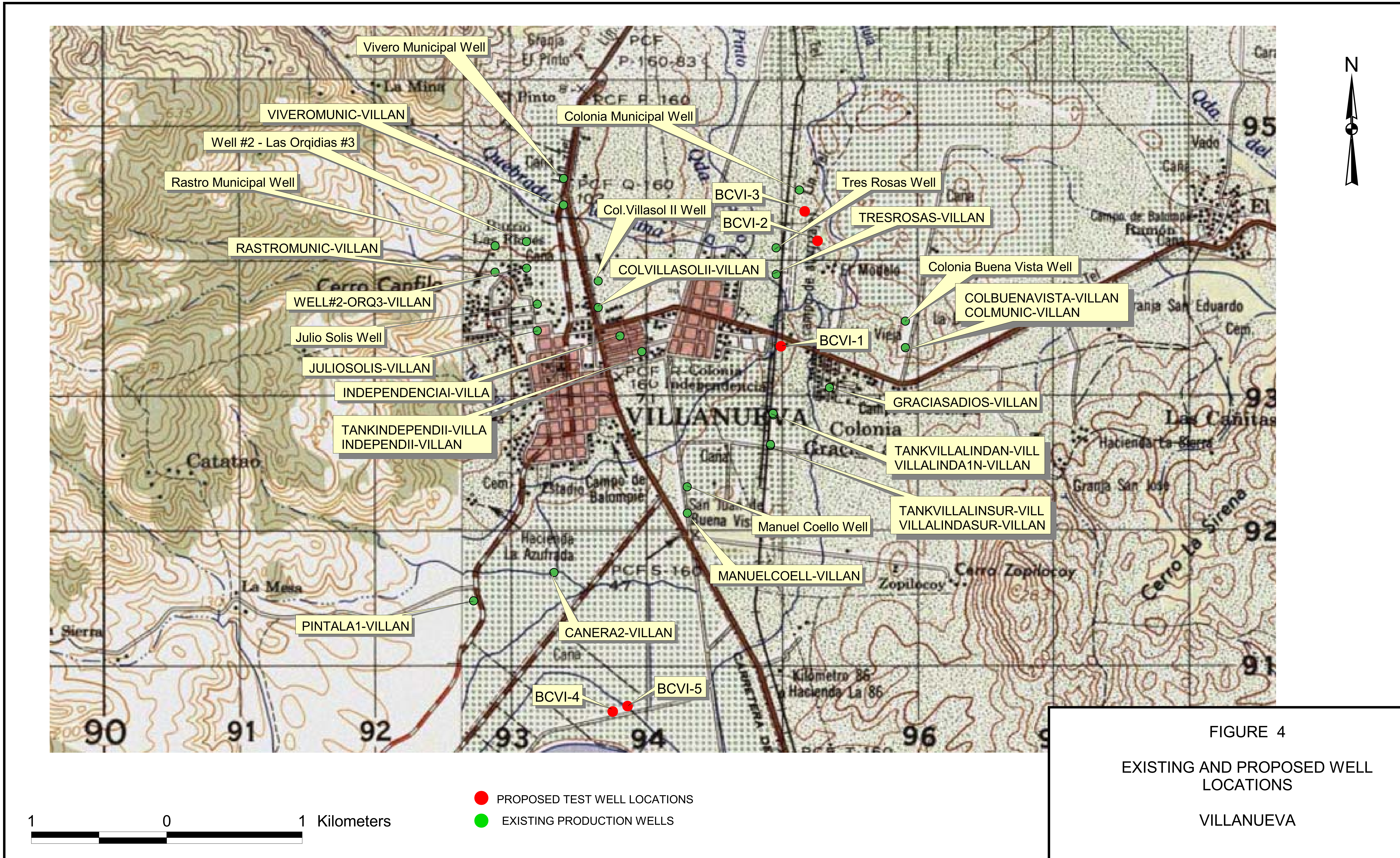


FIGURE 4

EXISTING AND PROPOSED WELL LOCATIONS

VILLANUEVA

RECOMMENDED FIELD ACTIVITIES

Geophysical Surveys

Down-hole geophysics will be conducted on each of the boreholes installed during this evaluation. The geophysical suite will include resistivity, spontaneous potential, gamma, and temperature.

Test and Monitoring Wells

We recommend the installation of two test wells (BCVI-1 and BCVI-2) and one monitoring well (BCVI-3) to evaluate the suspected buried channel deposits. The initial test well (BCVI-2) will be installed approximately 500 feet to the southeast of the Colonia Municipal Well (see Figure 4). This well will be drilled to a depth of 300 to 500 feet to evaluate the vertical extent of potential aquifers. Potential screen intervals will be based on field observations and bore-hole geophysics. If a viable aquifer is identified, a monitoring well (BCVI-3) will be installed approximately 300 feet southeast of the Colonia Municipal Well. This well will be screened in the same manner as BCVI-1.

The second test well (BCVI-1) will be installed to evaluate the suspected buried channel deposits. This well will be drilled to a depth of 300 to 500 feet to evaluate the vertical extent of potential aquifers. Potential well screen intervals will be based on field observations and borehole geophysics.

We also recommend that one monitoring well (BCVI-4) and one test well (BCVI-5) be installed to evaluate the Ulua River alluvium. These wells will be installed approximately 1.5 kilometers to the south of the two current municipal wells, Zona Cañera #2 and Zona Cañera #3 (see Figure 4). Prior to installing the test well, the monitoring well (BCVI-4) will be installed to characterize the vertical extent of alluvial materials. The estimated depth of the associated borehole is 500 to 700 feet. The monitoring well will be screened across the zone of highest potential production based on field observations and borehole geophysics. Approximately 100 feet from the monitoring well, a 12-inch diameter test well (BCVI-5) will be installed. The screen interval for the test well will be based on the information obtained from the monitoring well.

Aquifer Tests

Step testing and recovery testing will be conducted on each newly installed test well to calculate specific capacity, well efficiency, and transmissivity. The step test will be conducted over a 6 to 8 hour period. Following the step tests, the wells will be pumped at a constant rate for approximately 12 hours. During this test, drawdown and recovery data will be collected. The recovery data will be collected until the well has returned to within 90 percent of the original static water level.

Additionally, individual constant-rate pumping tests will be conducted on the test wells BCVI-2 and BCVI-5. The tests will be conducted for a minimum of 48 hours. The test well will be pumped at a rate sufficient to adequately stress the aquifer system, as determined during the step test. Drawdown associated with the BCVI-2 test well will be monitored in monitoring well BCVI-3 and the Colonia Municipal Well. Drawdown associated with the BCVI-5 well will be monitored in well BCVI-4.

Water Quality Sampling

Each interval that is identified as yielding a sufficient amount of groundwater will be tested for the following parameters:

- total dissolved solids
- specific conductance
- pH
- acidity
- alkalinity as $CaCO_3$
- nitrate/nitrite
- coliform
- chloride
- TAL metals (arsenic, barium, cadmium, chromium, iron, fluoride, lead, manganese, mercury, nickel, selenium, silver, sodium, and zinc)

ANTICIPATED FIELD RESULTS

The anticipated field results are as follows:

- Installation of the Ulua River alluvium river wells will provide information on the geometry of the aquifer system, aquifer transmissivities, aquifer specific yields, and yield sustainability.
- Installation of wells within the suspected buried channel deposits will provide information on the geometry of the aquifer system, boundary conditions, aquifer transmissivities, aquifer specific yields, and yield sustainability.
- Identification of groundwater production zones of suitable groundwater quality will assist in making recommendations for future wells.

APPENDIX B

Phase II Field Investigation Results

PHASE II FIELD INVESTIGATION RESULTS

Villanueva, Honduras

June 2002

1.0 INTRODUCTION

As part of Contract Number 522-C-00-01-00287-00, Phase 2 between United States Agency for International Development (USAID) and Brown and Caldwell, five wells were installed and tested at three sites in Villanueva. Work performed included drilling of exploratory boreholes, down-hole geophysical logs, installation of wells in exploratory boreholes, development of wells, and pump tests. This report provides details on the installation and testing of these wells.

The installed wells are named BCVI-1, BCVI-2, BCVI-3, BCVI-4, and BCVI-5. Figure 4-1, shown in Section 4 of this report, shows their location in relation to the surrounding municipality. The technical rationale for the location of each well was provided to USAID in the document entitled "Conceptual Model for Villanueva" and the technical procedures for conducting the work were outlined in the document entitled "Technical Procedure for Phase II Field Investigation Boreholes and Wells for Villanueva". The construction of the wells is summarized in Table B-1. The details of the work performed during the exploration, drilling, well construction and testing of each well are presented in the following sections.

Table B-1. Summary of Installed Wells

Name of Well	Total depth of borehole (feet, bgs)	Total depth of well (feet, bgs)
BCVI-1	465	448
BCVI-2	480	310
BCVI-3	340	317
BCVI-4	680	470
BCVI-5	480	466

bgs – below ground surface

2.0 EXPLORATORY BOREHOLES

At each location, an exploratory borehole was drilled first. Generally, this borehole was later reamed to a larger diameter to allow for the installation of a well. Each of the boreholes in Villanueva were drilled and installed by Servicios de Perforación, S. de R. L. de C. V. (SERPE). Details of borehole completion are provided in Table B-2. Completion of the boreholes was overseen by both Brown and Caldwell and Asesores Técnicos en Ingeniería y Ciencias Ambientales S. de R. L. (ATICA) staff.

Table B-2. Summary of Boreholes

Name of Well	BCVI-1	BCVI-2	BCVI-3	BCVI-4	BCVI-5
Name of Driller	SERPE	SERPE	SERPE	SERPE	SERPE
Date Started	8/18/2001	7/5/2001	7/31/2001	9/24/2001	11/2/2001
Date Completed	8/25/2001	7/22/2001	8/8/2001	10/13/2001	1/3/2002

Name of Well	BCVI-1	BCVI-2	BCVI-3	BCVI-4	BCVI-5
Drilling Equipment and Method	midway, mud rotary	midway, mud rotary	midway, mud rotary	midway, mud rotary	midway, mud rotary
Drilling Fluid	water, bentonite, and polymer	water, bentonite, and polymer	water, bentonite, and polymer	water, bentonite, and polymer	water, bentonite, and polymer
Drill Bit Diameter	8 ½ -inch	8 ½ -inch	8 ½ -inch	8 ½ -inch	24-inch
Total Borehole Depth (feet, bgs)	465	480	340	680	480
Penetration Rate (ft/hr)	6.4 – 37.5	4.0 – 29.0	4.2 – 17.6	4.8 – 34.3	not available
Geophysical Logging Company and Date	Brown and Caldwell, 8/25/2001	SERPE, 7/16/01	SERPE, 8/8/2001	SERPE, 10/13/2001	SERPE, 1/4/2002

ft=feet
bgs=below ground surface
hr=hour

Water used for drilling was obtained from various locations around the municipality of Villanueva. For example, the water for wells BCVI-1, BCVI-2, and BCVI-3 was obtained from local municipality wells near the well sites. The water for wells BCVI-4 and BCVI-5 was obtained from a lake in the nearby cañeras. This water was transported to the various sites and stored in a tanker truck (Figure B-1).

Continuous daily drilling was planned, however, occasional mechanical problems with the drill rigs and access problems caused by wet weather resulted in delays of approximately three to four weeks. Well BCVI-4 was delayed for two days during Hurricane Michelle at the end of September. Wells BCVI-1, BCVI-2, and BCVI-3 were already completed at the time of the storm. The storm is reported to have brought 20 inches of rain in two days and the river was reported to be 10 feet overbank with associated flooding in the cañeras. This flooding did not affect any wells installed in Villanueva. The drilling of borehole BCVI-5 was also delayed several times due to not having immediate right-of-entry permission, mechanical problems, and weather set-backs.

Figure B-1. Drill Rig at BC-VI-2 and Tanker Truck for Water Storage

3.0 LITHOLOGIC LOGGING

Figure B-2. Drill Cuttings being added to Chip Trays for Lithologic Logging

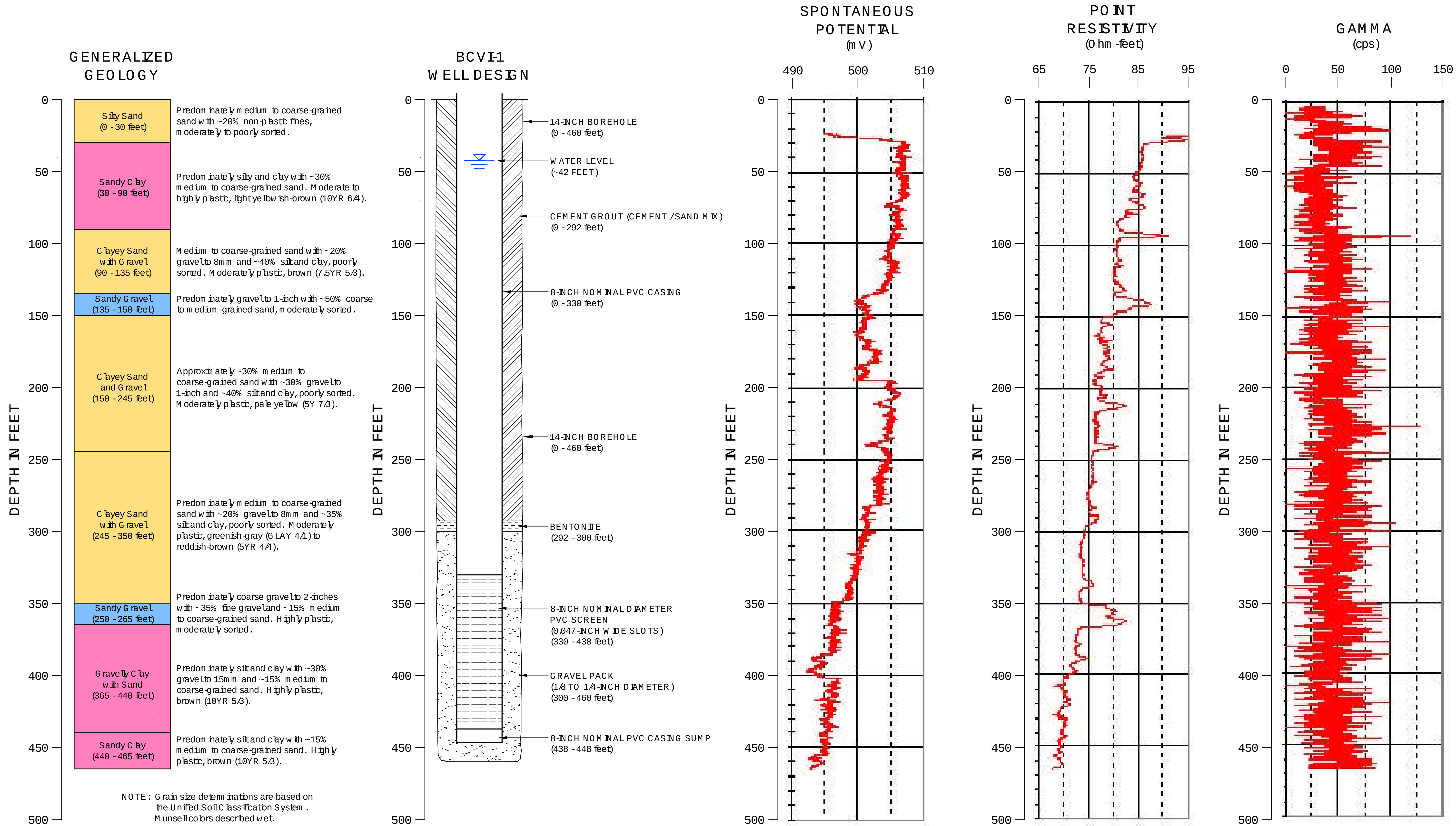
A lithologic log was prepared for each location that describes the stratigraphy penetrated throughout each borehole. The information for these logs came from drilled cuttings collected every 10 feet. Cuttings were collected from the drilling fluid with a slotted strainer and were preserved in plastic trays designed for this use (Figure B-2). Generalized lithologic logs, geophysical logs, and well designs for wells BCVI-1, BCVI-2, BCVI-3, BCVI-4, and BCVI-5 are presented on Figure B-3 through Figure B-7, respectively.

4.0 GEOPHYSICAL LOGGING

After completion of the exploratory boreholes, geophysical logging was conducted. The geophysical logging suite included spontaneous potential, electrical resistivity, and gamma ray logs for BCVI-1. The geophysical logging suite for boreholes BCVI-2, BCVI-3, BCVI-4, and BCVI-5 included spontaneous potential and point resistivity. The geophysical logs, lithology, and well designs for BCVI-1, BCVI-2, BCVI-3, BCVI-4 and BCVI-5 are presented on Figure B-3 through Figure B-7, respectively.

Exploratory borehole BCVI-1 penetrated silty-sand from land surface to approximately 9 m (30 ft) bgs. Interbedded deposits of gravel, sand, silt, and clay were encountered from approximately 9 to 134 m (30 to 440 ft) bgs. Interspersed with these layers are well developed sand and gravel deposits from approximately 41 to 46 m (135 to 150 ft) bgs and 107 to 111 m (350 to 365 ft) bgs. Sandy-clay was encountered from approximately 134 m (440 ft) to the total depth of the borehole at 142 m (465 ft) bgs and is interpreted to be alluvial in origin. The interbedded gravel, sand, silt, and clay deposits are interpreted to be fluvial over-bank deposits. The sand and gravel deposits are interpreted to be river channel deposits associated with ancestral rivers that meandered throughout the Sula Valley.

The exploratory borehole for BCVI-2 penetrated predominantly fine-grained deposits from land surface to approximately 69 m (225 ft) bgs, however a gravel lens was encountered from approximately 21 to 29 m (70 to 95 ft) bgs. In addition, a well-developed gravel and cobble deposit was encountered from approximately 69 to 94 m (225 to 310 ft) bgs. Sandy-clay was penetrated from the bottom of the gravel and cobble deposit to the total depth of the borehole at 146 m (480 ft) bgs. Well BCVI-3 was installed as an observation well approximately 30 m (98 ft) northwest of BCVI-2. The geology encountered at observation well BCVI-3 was similar to that of test well BCVI-2.



BROWN AND CALDWELL

Figure B-3

TEST WELL BCVI-1

VILLANUEVA, HONDURAS

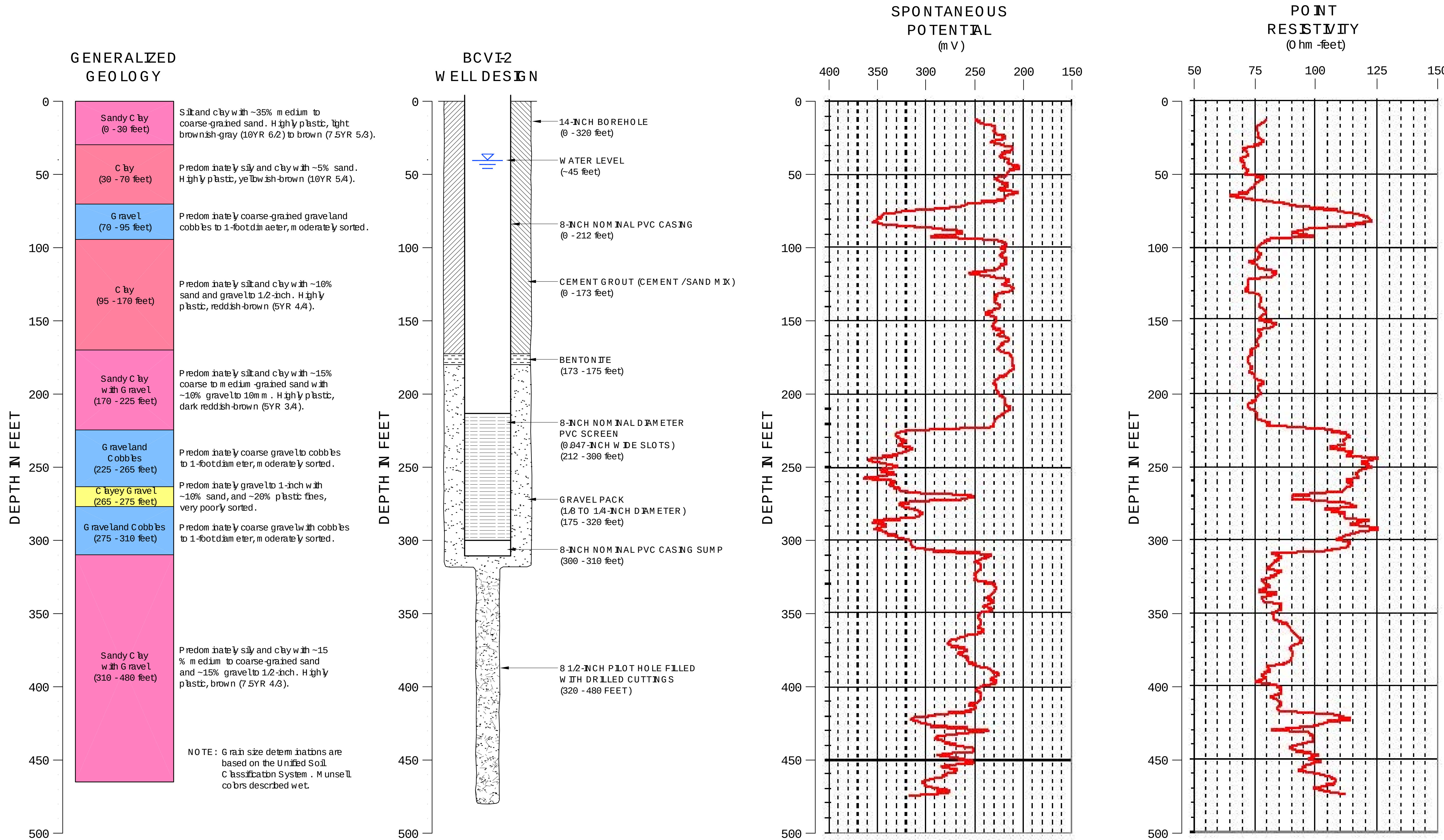


Figure B-4
TEST WELL BCVI-2
VILLANUEVA, HONDURAS

BROWN AND CALDWELL

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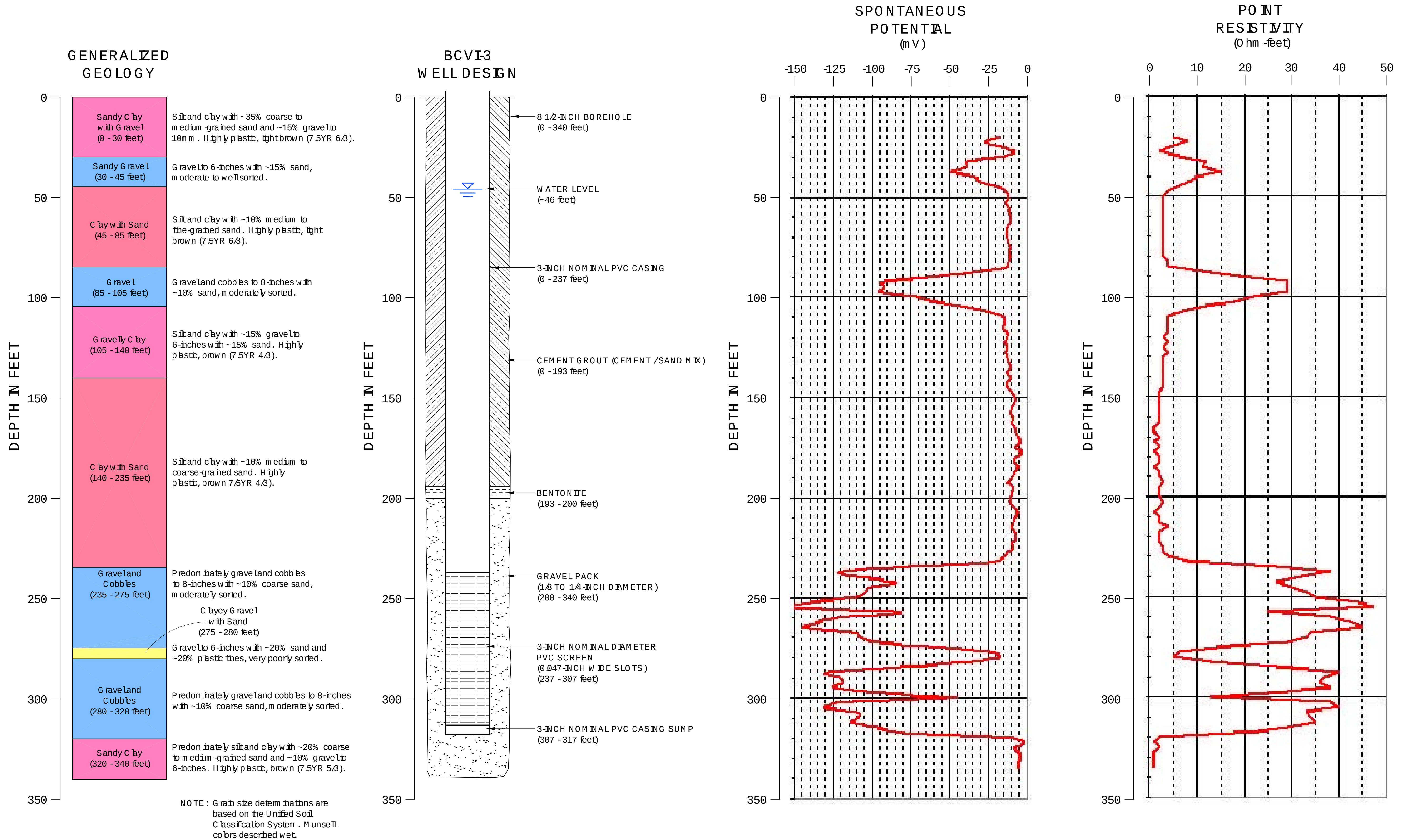

Figure B-5
TEST WELL BCVI-3
VILLANUEVA, HONDURAS

BROWN AND CALDWELL

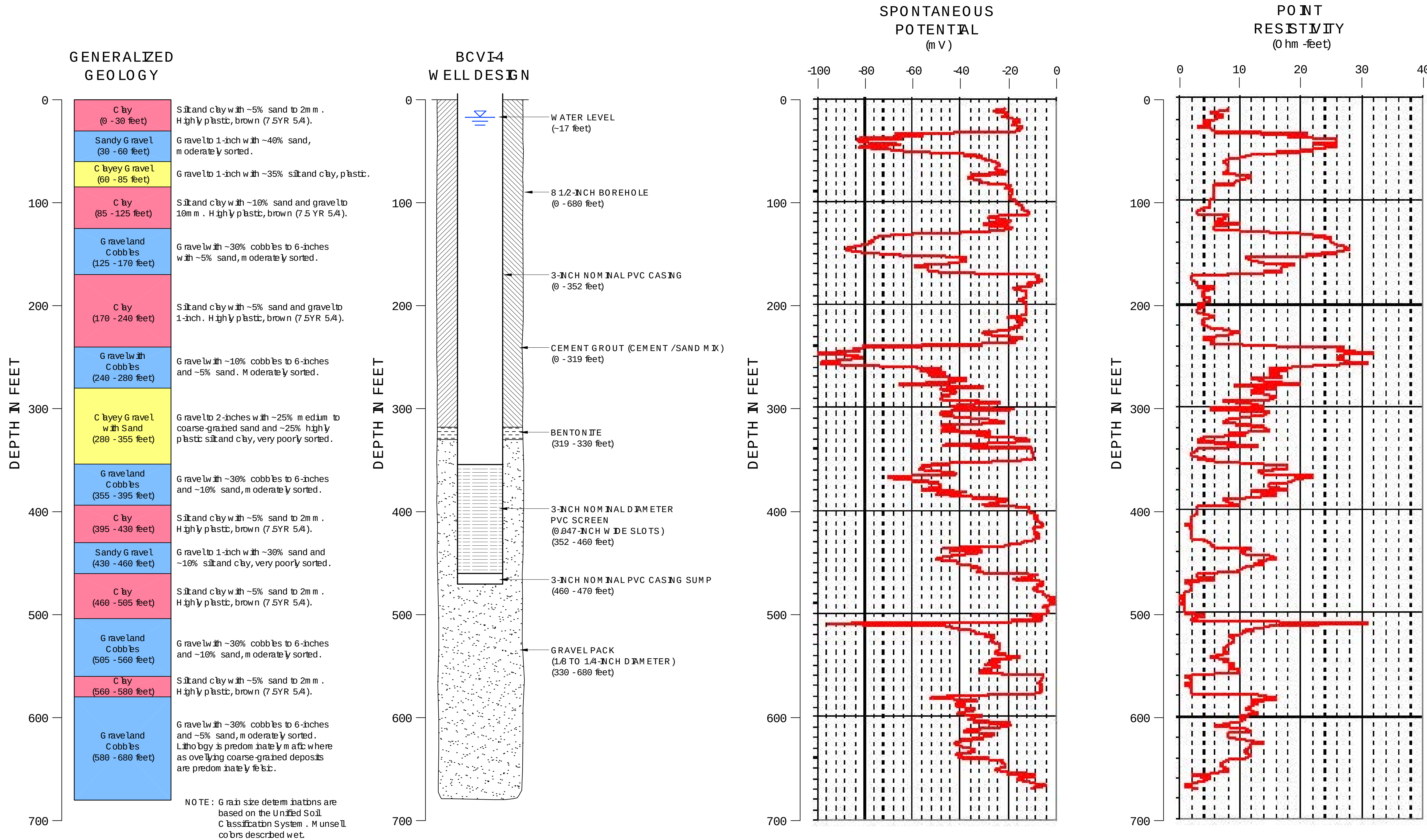

Figure B-6
TEST WELL BCVI-4
VILLANUEVA, HONDURAS

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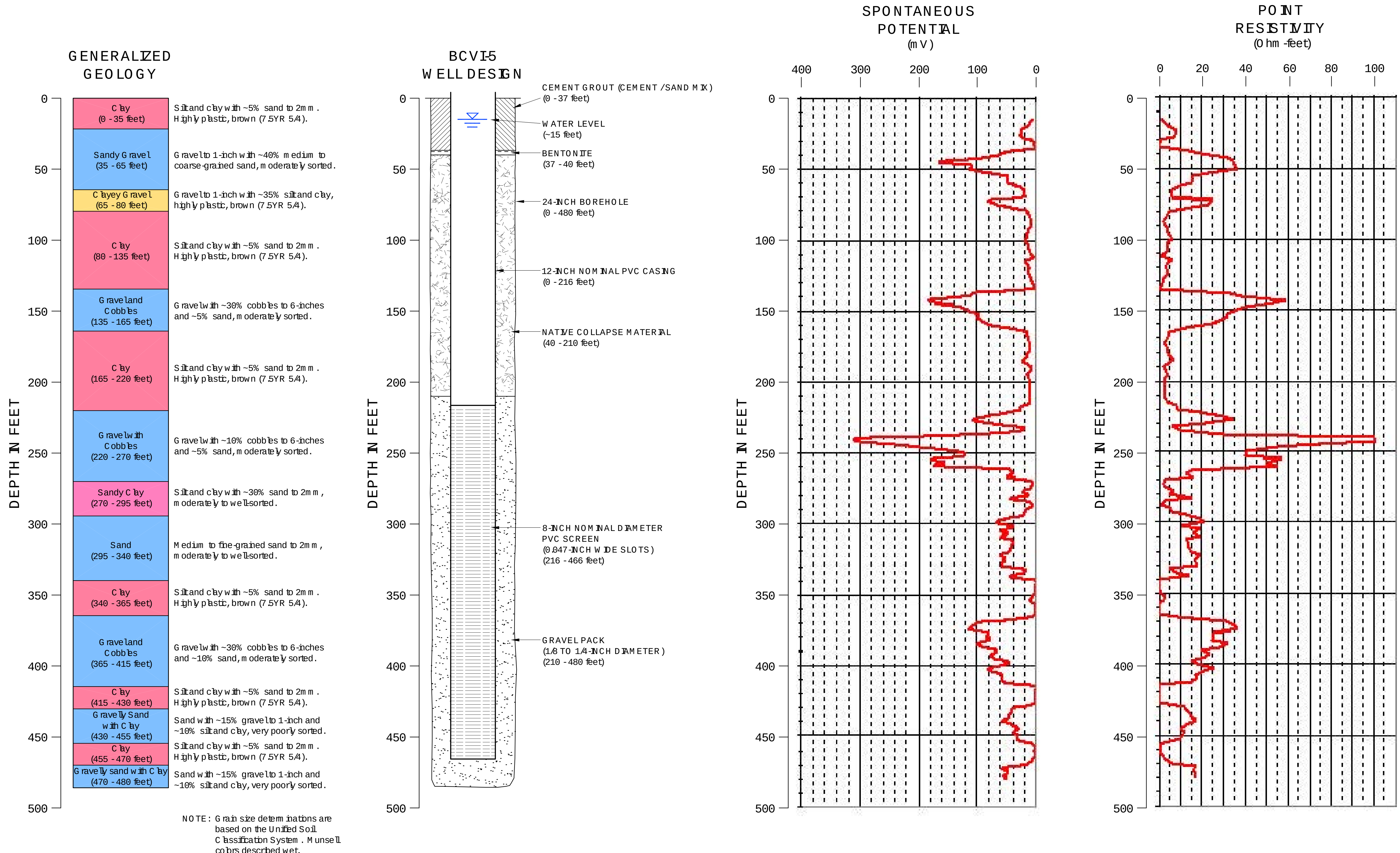

BROWN AND CALDWELL

Figure B-7

TEST WELL BCVI-5

VILLANUEVA, HONDURAS

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At observation well BCVI-4, alternating fine-grained and coarse-grained alluvial and fluvial deposits, generally 9 to 18 m (30 to 60 ft) thick, were encountered from the surface to total depth of the borehole. Additionally, interbedded deposits of gravel, sand, silt, and clay were penetrated from approximately 85 to 108 m (280 to 355 ft) bgs. The fine-grained deposits included silt and clay with up to 10 percent sand. The coarse-grained deposits are generally comprised of gravel and cobbles. In general, the upper part of the coarse-grained deposits are host to felsic minerals, whereas the lithology in the lower portion of the deposit is predominately mafic in origin. The mafic gravel and cobbles, deposited from 177 m (580 ft) bgs to the total depth of the borehole at 207 m (680 ft) bgs, is interpreted to be reworked volcanic deposits. BCVI-4 was completed as an observation well and was installed approximately 100 m (328 ft) south of BCVI-5. The lithology encountered at test well BCVI-5 was similar to that of observation well BCVI-4.

5.0 WELL DESIGN

Each of the wells in Villanueva were designed to produce water from saturated sand and gravel alluvial deposits. Blank polyvinyl chloride (PVC) casing was installed (Figure B-8) from land surface to the top of the screened interval. The water bearing units were screened with slotted PVC casing. A gravel pack was installed adjacent to the screened interval and was isolated from the upper portion of the borehole with a thin layer of bentonite chips and a sanitary seal. The sanitary seal consists of sand/cement grout installed from the top of the bentonite layer to land surface.

Figure B-8. Installation of PVC Casing at BCVI-2

The drilled cuttings and geophysical logs were analyzed to determine the depth of the production zones to be screened by the well. At BCVI-1, the production zone included a sandy gravel deposit from approximately 250 to 265 feet below ground surface (bgs) that was overlain by a clayey sand deposit, and underlain by a gravelly-clay deposit. At BCVI-2 and BCVI-3, the production zone of the well was comprised of a gravel and cobble deposit that was penetrated from approximately 225 to 320 feet bgs. At BCVI-4 and BCVI-5, the interval between approximately 220 and 460 feet bgs was identified as the most prominent water-bearing unit encountered at the site.

The diameter of each well was based on the purpose of the well and the estimated yield from evaluation of lithologic log, drilling penetration rate, and geophysical logs. Wells BCVI-1 and BCVI-2 were completed with 8-inch PVC casing. Wells BCVI-3 and BCVI-4 were utilized as observation wells and were constructed with 3-inch PVC casing. BCVI-5 was constructed with 12-inch PVC casing to accommodate a large-diameter pump because it was expected to yield a significantly higher volume of water than the other test wells installed in Villanueva.

6.0 WELL CONSTRUCTION

Wells were constructed after reaming the exploratory boreholes to the final diameter. Both Brown and Caldwell and ATICA staff provided oversight during well completion. Well construction details for BCVI-1, BCVI-2, BCVI-3, BCVI-4, and BCVI-5 are presented on Figure B-3 through Figure B-7, respectively, and are summarized in Table B-3.

Table B-3. Summary of Well Construction

Name of Well	BCVI-1	BCVI-2	BCVI-3	BCVI-4	BCVI-5
Date Started	9/1/2001	7/23/2001	8/9/2001	10/19/2001	1/4/2002
Date Completed	9/2/2001	7/24/2001	8/9/2001	10/20/2001	1/6/2002
Diameter of Borehole	14-inch	14-inch	8 ½ -inch	8 ½ -inch	24-inch
Total Depth of Well (feet, bgs)	448	310	317	470	466
Casing/ Screen Material	8-inch nominal PVC casing	8-inch nominal PVC casing	3-inch nominal PVC casing	3-inch nominal PVC casing	12-inch nominal PVC casing
Screen Interval (feet, bgs)	330 - 438	212 - 300	237 - 307	352 - 460	216 - 466
Screen Slot Size	0.05-inch	0.05-inch	0.05-inch	0.05-inch	0.05-inch
Sanitary Seal Material	sand/cement grout	sand/cement grout	sand/cement grout	sand/cement grout	sand/cement grout
Sanitary Seal Interval (feet, bgs)	0 - 292	0 - 173	0 - 193	0 - 325	0 – 37*
Bentonite Seal Interval (feet, bgs)	292 - 300	173 - 175	193 - 200	319 - 330	37 - 40*
Gravel Pack Material	1/8 to 1/4 – inch gravel	1/8 to 1/4 – inch gravel	1/8 to 1/4 – inch gravel	1/8 to 1/4 – inch gravel	1/8 to 1/4 – inch gravel
Gravel Pack Interval (feet, bgs)	300 - 460	175 – 320	200 - 340	330 - 680	210 - 480*

*These depths are estimated. During installation of the gravel pack, the borehole collapsed and filled the annulus from approximately 40 to 210 feet . Following the collapse, the bentonite seal and the sand/cement grout were installed.
bgs=below ground surface

The surface completion of each well consisted of a concrete block housing for the wellhead including a locking steel cover. Additionally, each well includes a stainless steel plaque that identifies the well.

7.0 WELL DEVELOPMENT

Following installation of casing, wells BCVI-1, BCVI-2, and BCVI-5 were developed by the swab and airlift method. Observation wells BCVI-3 and BCVI-4 were developed by airlift due to the small casing diameter. Airlifting was conducted at various rates and was continued until the produced groundwater was clear and free of sand and silt. Activities related to well development are summarized in Table B-4.

Table B-4. Well Development Summary

Name of Well	BCVI-1	BCVI-2	BCVI-3	BCVI-4	BCVI-5
Date Started	9/9/2001	7/25/2001	8/10/2001	10/22/2001	1/6/2002
Date Ended	9/10/2001	7/26/2001	8/11/2001	10/23/2001	1/9/2002
Total Hours	10.5	8	9.5	9.5	30
Description of Method	Swab and Airlift	Swab and Airlift	Airlift	Airlift	Swab and Airlift

8.0 AQUIFER DISCHARGE TESTS

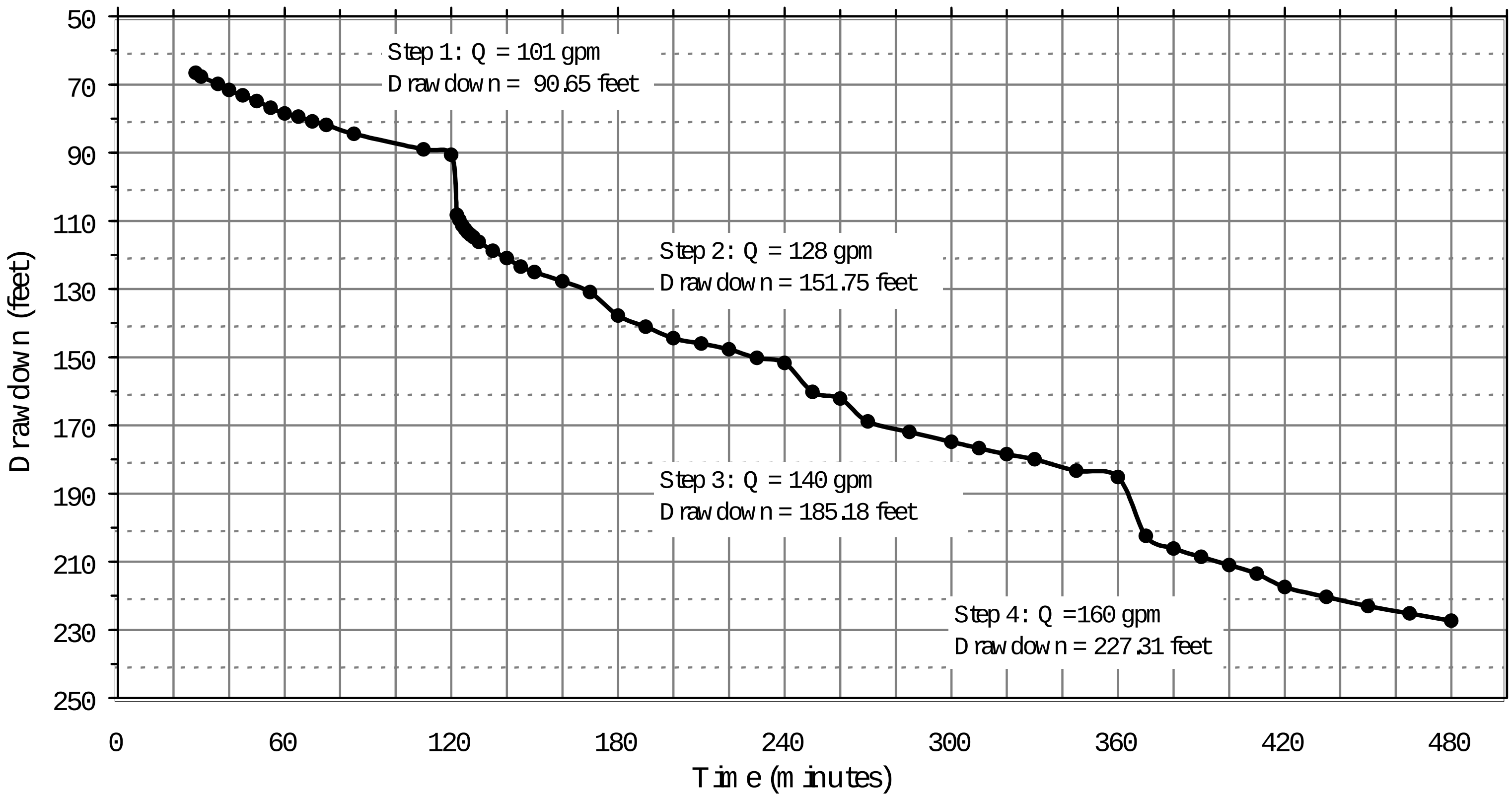
Aquifer discharge tests consisting of step rate discharge tests, well aquifer tests, and constant rate discharge tests were conducted as part of the field investigation. This section describes these tests and their results.

A step rate discharge test was conducted to evaluate the specific capacity of each well and to collect data to be used in groundwater modeling. The purpose of a step rate discharge test is to determine the maximum pumping potential of the well. A step rate discharge test was not conducted at wells BCVI-3 and BCVI-4. These wells were utilized as observation wells to monitor water levels during the testing of pumping wells BCVI-2 and BCVI-5, respectively. Drawdown plots for the step rate discharge tests at wells BCVI-1, BCVI-2, and BCVI-5 are presented on Figure B-9, Figure B-10, and Figure B-11, respectively. The step rate discharge tests for BCVI-1, BCVI-2 and BCVI-5 are summarized in Table B-5 and Table B-6.

Table B-5. Summary of Step Rate Discharge Tests

Name of Well	BCVI-1	BCVI-2	BCVI-5
Duration (hours)	8	7.5	~7.5
Start Date	9/14/2001	8/15/2001	1/17/2002
Pump Size/Type	40 HP Submersible	40 HP Submersible	40 HP Submersible
Pump Depth - ft, bgs	~300	~200	~140
Static Water Level - ft, bgs	41.90	45.71	10.66
Specific Capacity - gpm/ft	1.1 @ 101 gpm 0.8 @ 128 gpm 0.8 @ 140 gpm 0.7 @ 160 gpm	12.3 @ 151 gpm 11.1 @ 225 gpm 10.6 @ 300 gpm 10.1 @ 375 gpm 8.3 @ 450 gpm	22.5 @ 500 gpm 21.0 @ 600 gpm 20.0 @ 710 gpm 19.2 @ 795 gpm 18.3 @ 1,000 gpm

hp=horse power
ft=feet
gpm=gallons per minute



Q - Discharge Rate
gpm - gallons per minute

BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BCVI-1	Figure B-9 STEP-RATE PUMPING TEST

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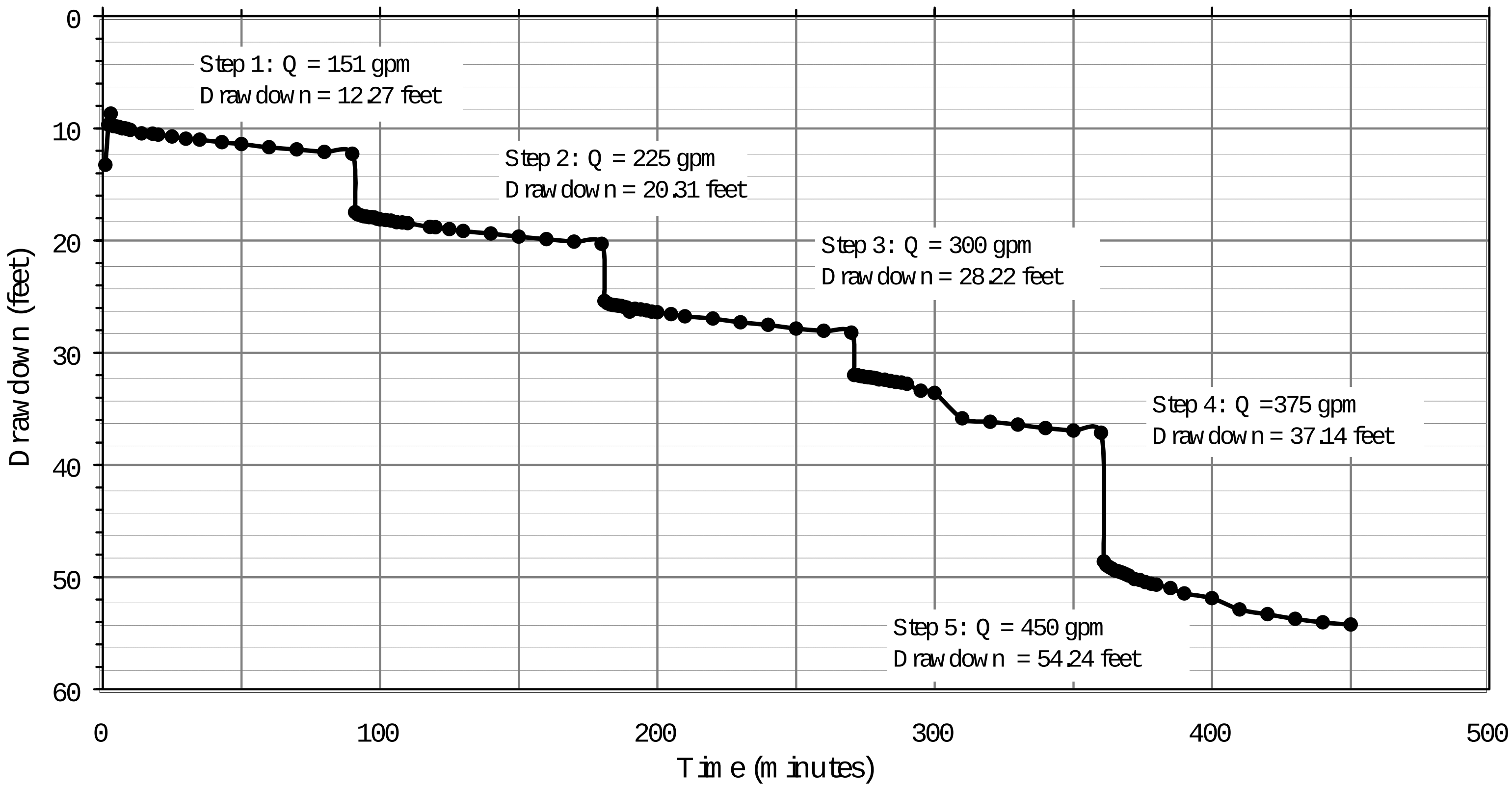

Q - Discharge Rate
gpm - gallons per minute

BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BC VI-2	Figure B-10 STEP-RATE PUMPING TEST

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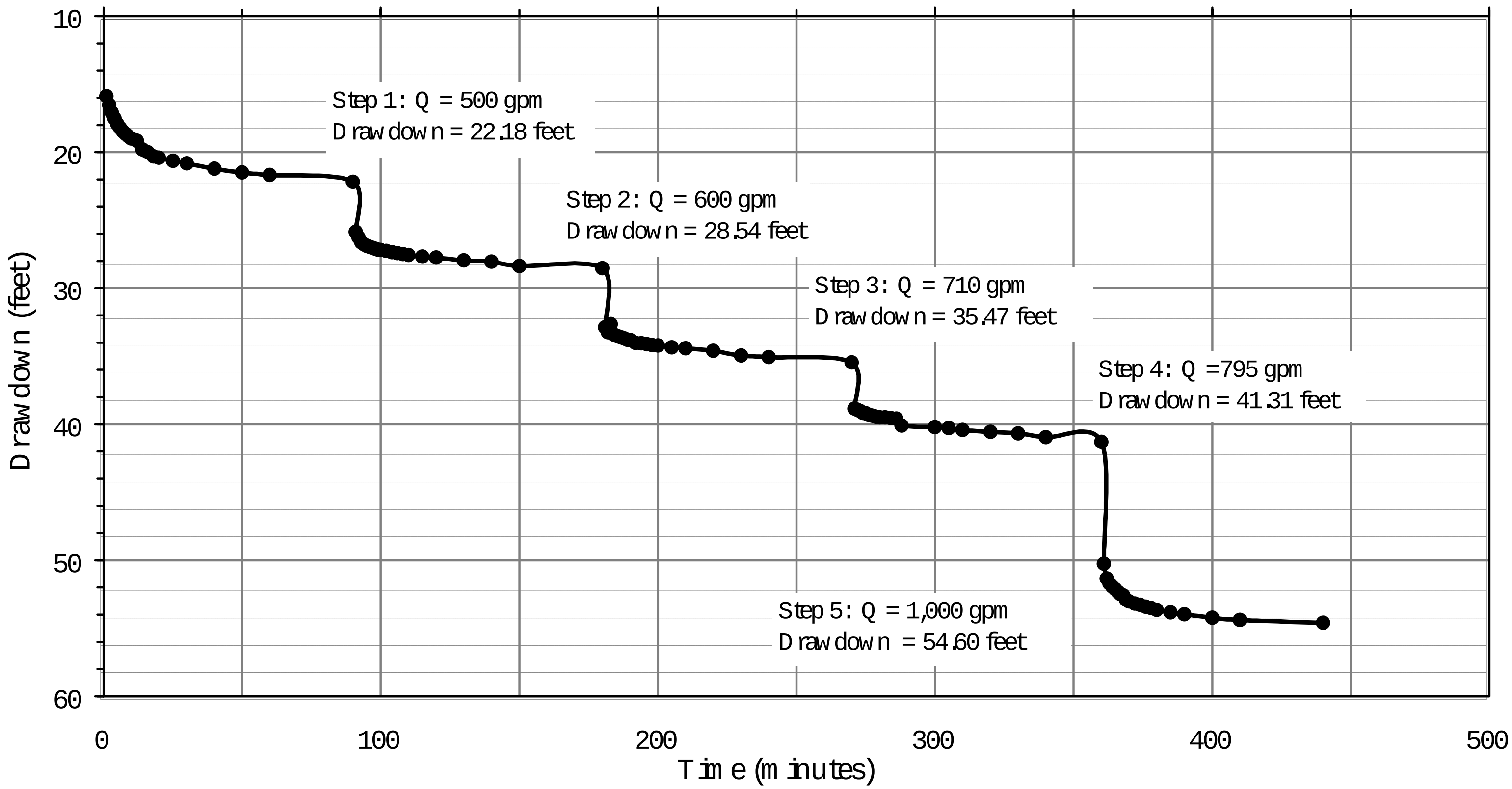

Q - Discharge Rate
gpm - gallons per minute

BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BCVI-5	Figure B-11 STEP-RATE PUMPING TEST

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Table B-6. Summary of Step Rate Discharge Tests

Name of Well	BCVI-1	BCVI-2	BCVI-5
PH	6.91 @ 101 gpm 6.92 @ 128 gpm 6.90 @ 140 gpm 6.91 @ 160 gpm	6.98 @ 151 gpm 7.04 @ 225 gpm 7.06 @ 300 gpm 7.07 @ 375 gpm 7.10 @ 450 gpm	6.79 @ 500 gpm 6.83 @ 600 gpm 7.00 @ 710 gpm 6.98 @ 795 gpm 7.01 @ 1,000 gpm
Temperature (degrees F)	87.5 @ 101 gpm 86.8 @ 128 gpm 83.8 @ 140 gpm 84.7 @ 160 gpm	96.1 @ 151 gpm 98.6 @ 225 gpm 98.6 @ 300 gpm 96.1 @ 375 gpm 96.4 @ 450 gpm	96.4 @ 500 gpm 98.7 @ 600 gpm 98.6 @ 710 gpm 97.2 @ 795 gpm 98.1 @ 1,000 gpm
Conductivity (µSemens per cm)	925 @ 101 gpm 863 @ 128 gpm 999 @ 140 gpm 900 @ 160 gpm	926 @ 151 gpm 901 @ 225 gpm 881 @ 300 gpm 924 @ 375 gpm 679 @ 450 gpm	926 @ 500 gpm 887 @ 600 gpm 938 @ 710 gpm 947 @ 795 gpm 986 @ 1,000 gpm

*Data presented for each step represent an average of independent readings spread over the course of each step.
F=degrees Farenheit
gpm=gallons per minute

A multiple well aquifer test was conducted at two of the three drilling sites in Villanueva. For the purpose of this project, a two well test was completed. Each multiple well test included a pumping well and an associated observation well. The purpose of an observation well is to document the zone of influence created by the pumping well. Well BCVI-3 served as the observation well for test well BCVI-2. Similarly, BCVI-4 served as the observation well for test well BCVI-5.

The purpose of a constant rate discharge test is to determine how the aquifer behaves when subjected to continual pumping at a constant discharge rate over an extended period of time. A constant rate discharge test was performed at each pumping well in Villanueva with the exception of BCVI-1 due to the low specific capacity of the well measured during the step rate test.

During each test, drawdown data was collected with a water level indicator (Figure B-12). After pumping was complete, recovery water levels were recorded, generally until the water level in the pumping well achieved 95 percent recovery.

Figure B-12. Water Level Indicator

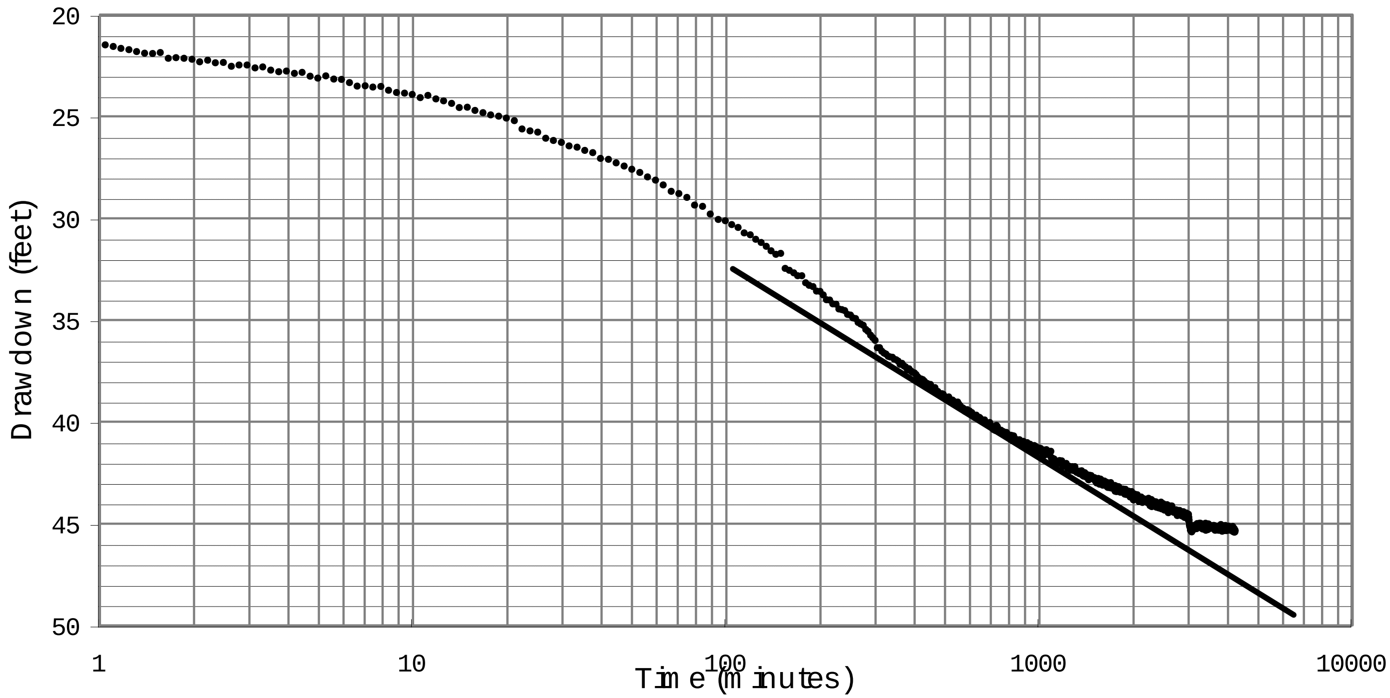
Transmissivity was calculated using the Cooper-Jacob method (Cooper and Jacob, 1946) for analyzing non-equilibrium flow in a confined aquifer system. This method utilizes a semi-log plot of drawdown verses time. Transmissivity can be estimated by measuring the slope of the drawdown plot. An analysis of the water-level recovery test data was used as a verification of aquifer parameters estimated from the constant-rate pumping test. Recovery tests are a more accurate method of estimating aquifer characteristics due to the absence of pumping effects on the water levels. Recovery test data were analyzed using the Theis recovery method (Theis, 1935), which utilizes a semi-log plot of drawdown, verses the time since the pump test started, divided by the time since the recovery test started. Transmissivity is estimated from the slope of the recovery plot. Drawdown data from the observation well allows for the estimation of the storage coefficient. The drawdown and recovery plots for BCVI-2 and BCVI-3 are presented on Figure B-13 through Figure B-16. The drawdown and recovery plots for BCVI-4 and BCVI-5 are presented on Figure B-17 through Figure B-20.

General test information and preliminary analysis of the results of the constant rate tests are also included in Table B-7. A narrative description of the aquifer discharge tests performed on each well is presented below:

An eight-hour step-rate discharge test was conducted at BCVI-1 at rates between approximately 379 and 606 lpm (100 and 160 gpm) on September 14, 2001. Static water level was measured at approximately 13 m (42 ft) bgs. During this test, the specific capacity (defined as the well yield per unit of draw-down) of each step ranged between 1.1 and 0.7 gallons per minute per foot (gpm/ft). At the maximum rate of 606 lpm (160 gpm), draw-down was approximately 69 m (227 ft) at the end of the test. Given these test results, the production from well BCVI-1 is considered poor.

Short-term and long-term aquifer tests were conducted at test well BCVI-2. During this test, well BCVI-3 was utilized as an observation well. A 7.5-hour step-rate discharge test was conducted at BCVI-2 on August 15, 2001. Measured static water level was approximately 14 m (46 ft) bgs. The well was pumped at five step-rates calculated to be approximately 568, 852, 1,136, 1,420, and 1,703 lpm (150, 225, 300, 375, and 450 gpm). At a maximum rate of 1,703 lpm (450 gpm), the maximum draw-down at the end of the test was approximately 16 m (54 ft). Specific capacities measured during the step-rate discharge test ranged between approximately 12.3 to 8.3 gpm/ft. The constant-rate discharge test at BCVI-2 commenced on August 16, 2001. The test well was pumped at an average rate of approximately 1,408 lpm (372 gpm) for 70.5 hours. Static water levels in wells BCVI-2 and BCVI-3 were measured at approximately 14 m (46 ft) bgs prior to the constant-rate discharge test. At the end of the test, total draw-downs at BCVI-2 and BCVI-3 resulted in water levels of 28 and 22 m (91 and 72 ft) bgs respectively, and the specific capacity of the test well was approximately 8.2 gpm/ft. After the pump test was complete, recovery water levels were recorded. After approximately 11.5 hours, water levels recovered 100 percent in BCVI-2 and 79 percent at well BCVI-3 . The analysis of the long-term aquifer test data indicates the transmissivity of the aquifer (the measurement of the rate at which water flows through a vertical strip of the aquifer under a hydraulic gradient of 100 percent) to be between 7,800 and 9,800 gallons per day per foot (gpd/ft).

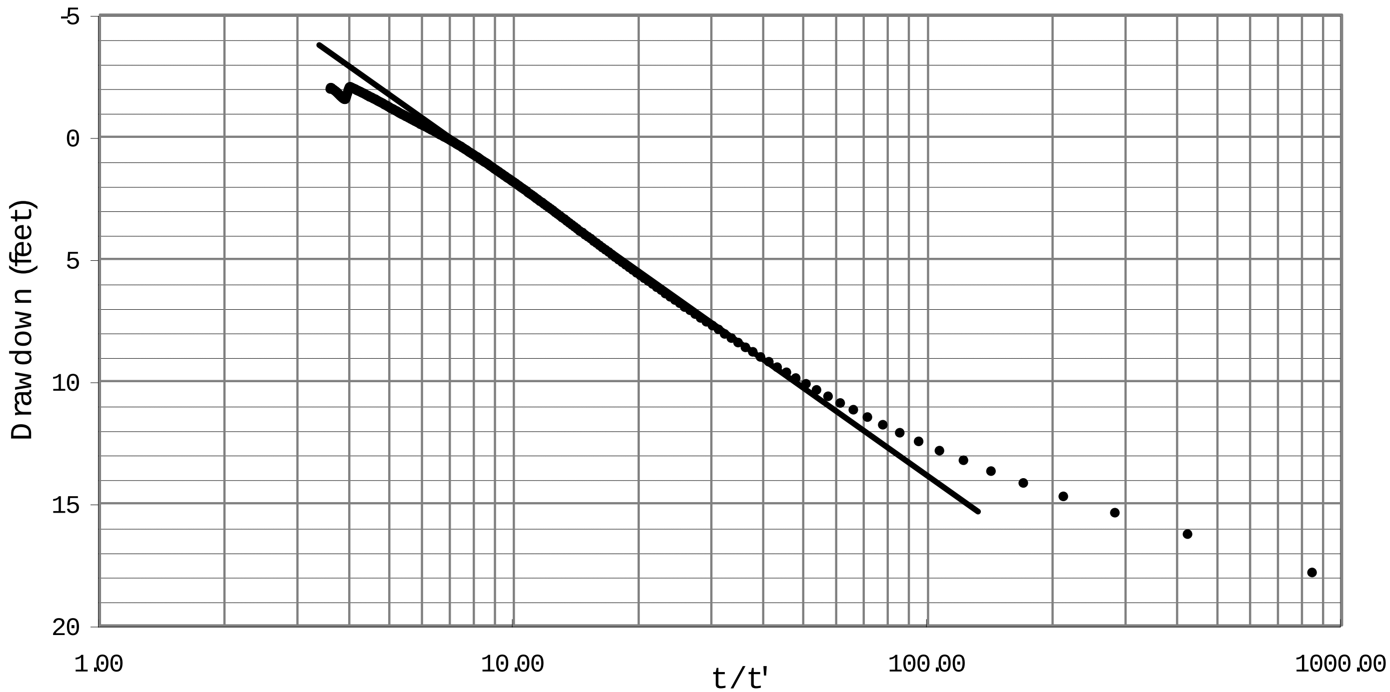
Short-term and long-term aquifer discharge tests were conducted at test well BCVI-5, with well BCVI-4 utilized as an observation well. A 7.5-hour step-rate discharge test was conducted at BCVI-5 on January 17, 2002. The initial static water level was approximately 11 feet bgs. The well was pumped at five step-rates of approximately 1,893, 2,271, 2,688, 3,009, and 3,785 lpm (500, 600, 710, 795, and 1,000 gpm). At a maximum rate of 3,785 lpm (1,000 gpm), the maximum groundwater



Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(372)/(10.8)
T ~ 9,100 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BC VI-2	Figure B-13 COOPER-JACOB PLOT



t = time since pumping started (min)
t' = time since pumping ended (min)
Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(372)/(12.4)
T ~ 7,900 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BC VI-2	Figure B-14 THEIS RECOVERY PLOT

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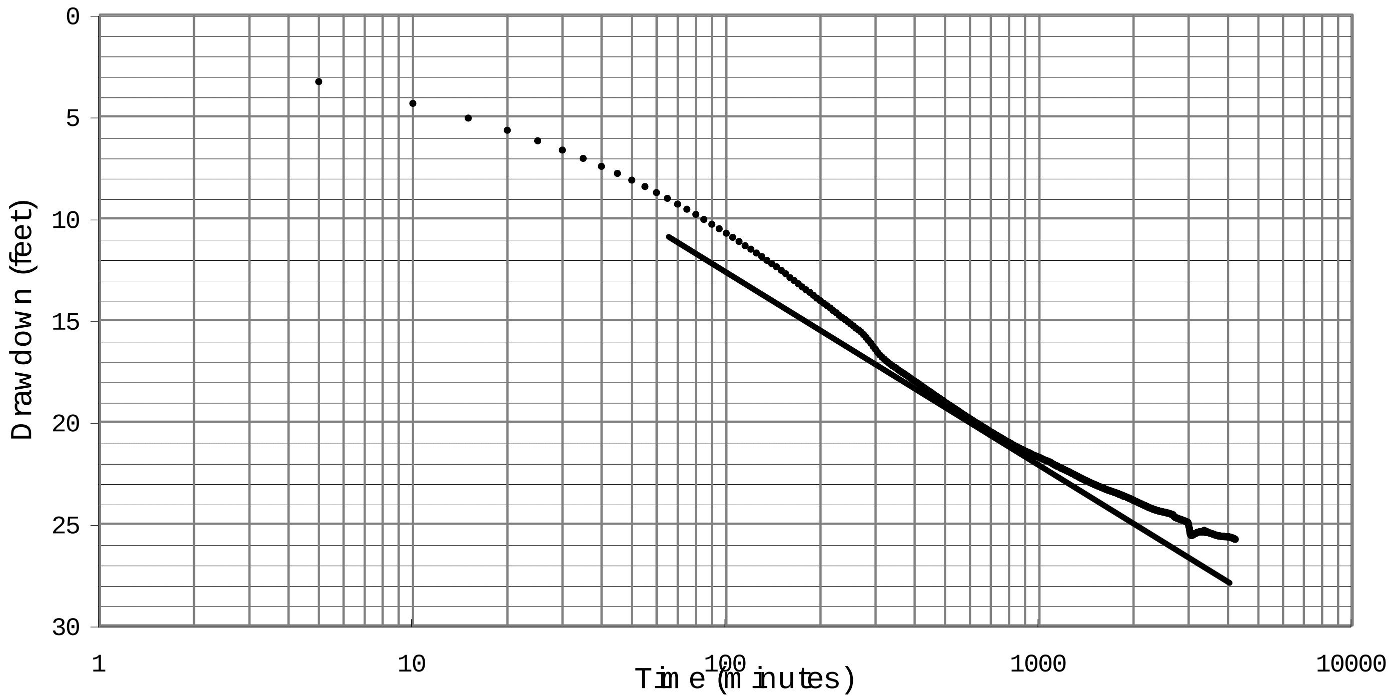


Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

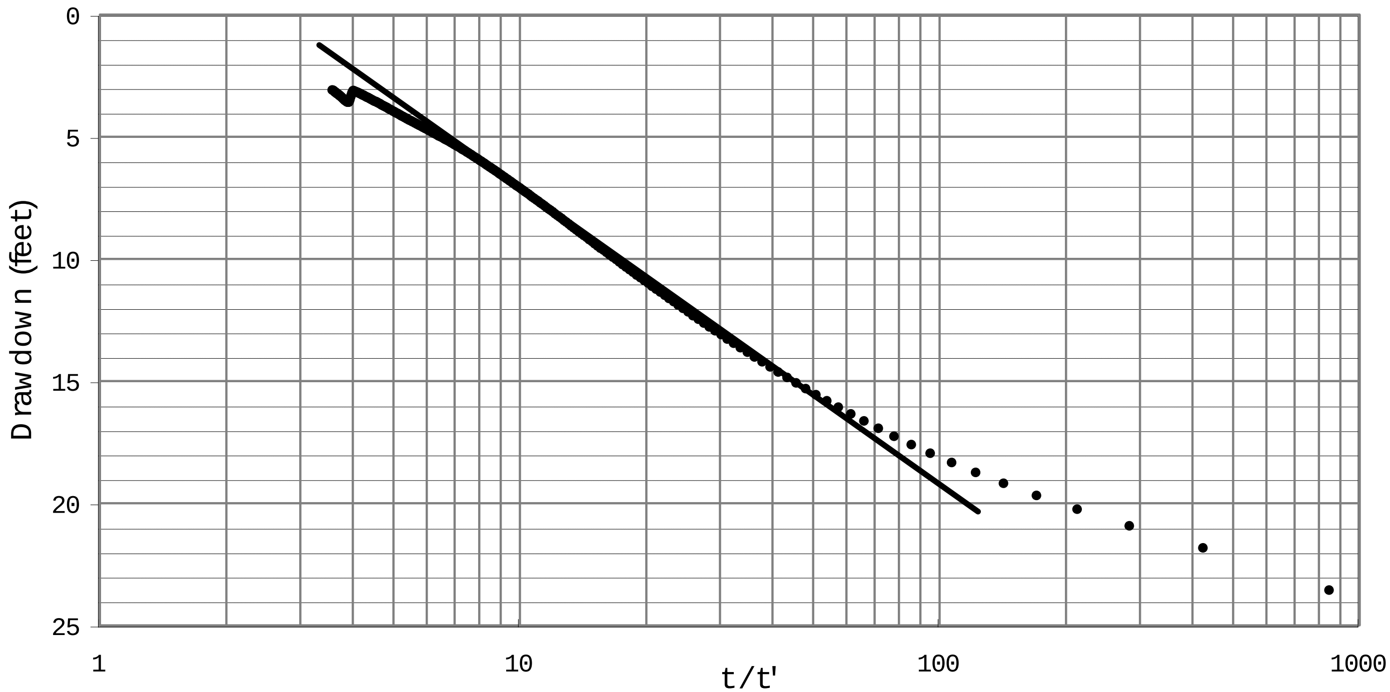
S = Storage Coeficient
t = Time where slope intersects zero drawdown (days)
r = Distance from pumping well (feet)

Note: Test Well BC VI-2 was the pumping well, ~103 feet away.

T = (264)(372)/(10.0)
T ~ 9,800 gpd/ft

S = (0.3)Tt/(r^2)
S = (0.3)(9,800)(0.0045)/(103^2)
S = 0.0012

BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BC VI-3	Figure B-15 COOPER-JACOB PLOT



t = time since pumping started (min)
t' = time since pumping ended (min)
Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(372)/(12.6)
T ~ 7,800 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BC VI-3	Figure B-16 THEIS RECOVERY PLOT

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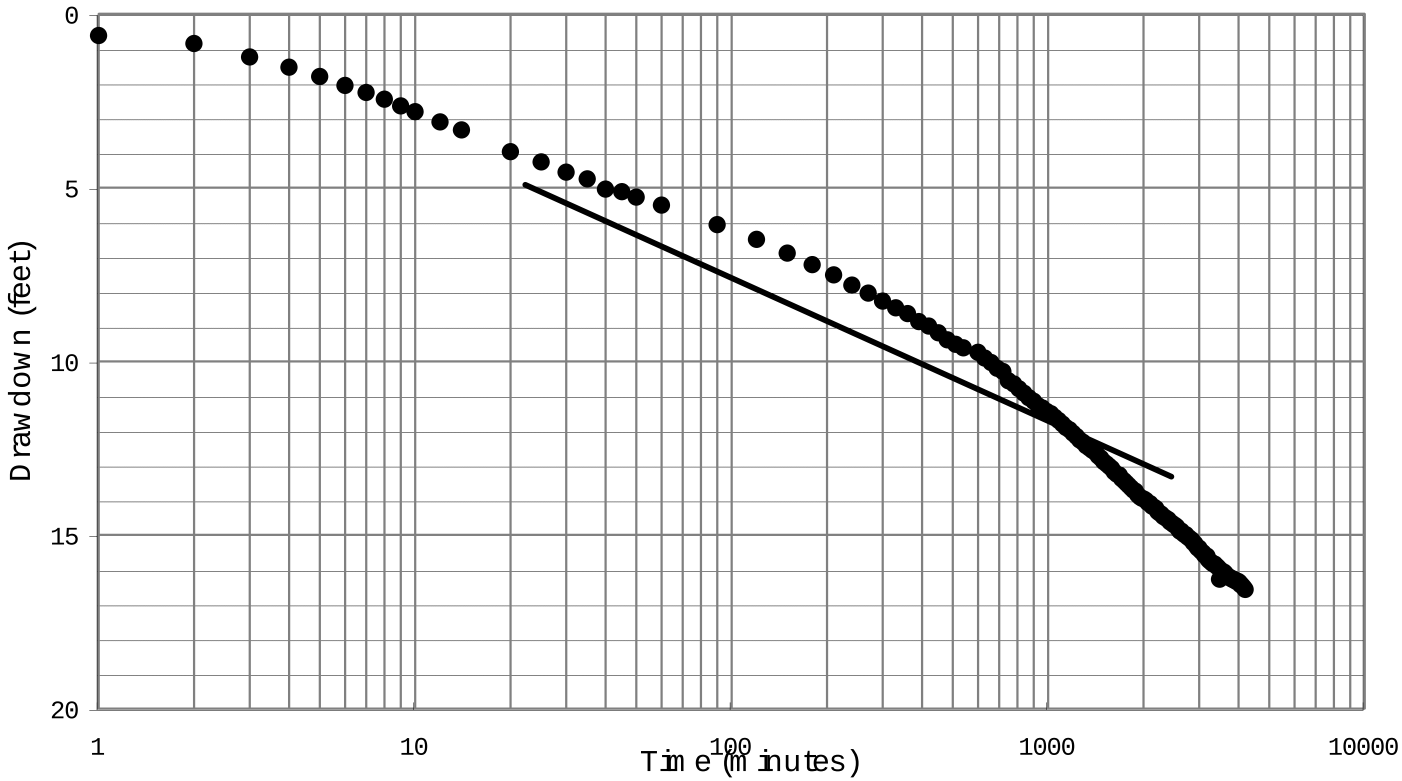

Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

S = Storage Coeficient
t = Time where slope intersects zero drawdown (days)
r = Distance from pumping well (feet)

Note: Test Well BCVI-5 was the pumping well, ~390 feet away.

T = (264)(900)/(5.8)
T ~ 41,000 gpd/ft

S = (0.3)Tt/(r^2)
S = (0.3)(41,000)(0.0042)/(390^2)
S = 0.0003

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BCVI-4	Figure B-17 COOPER-JACOB PLOT

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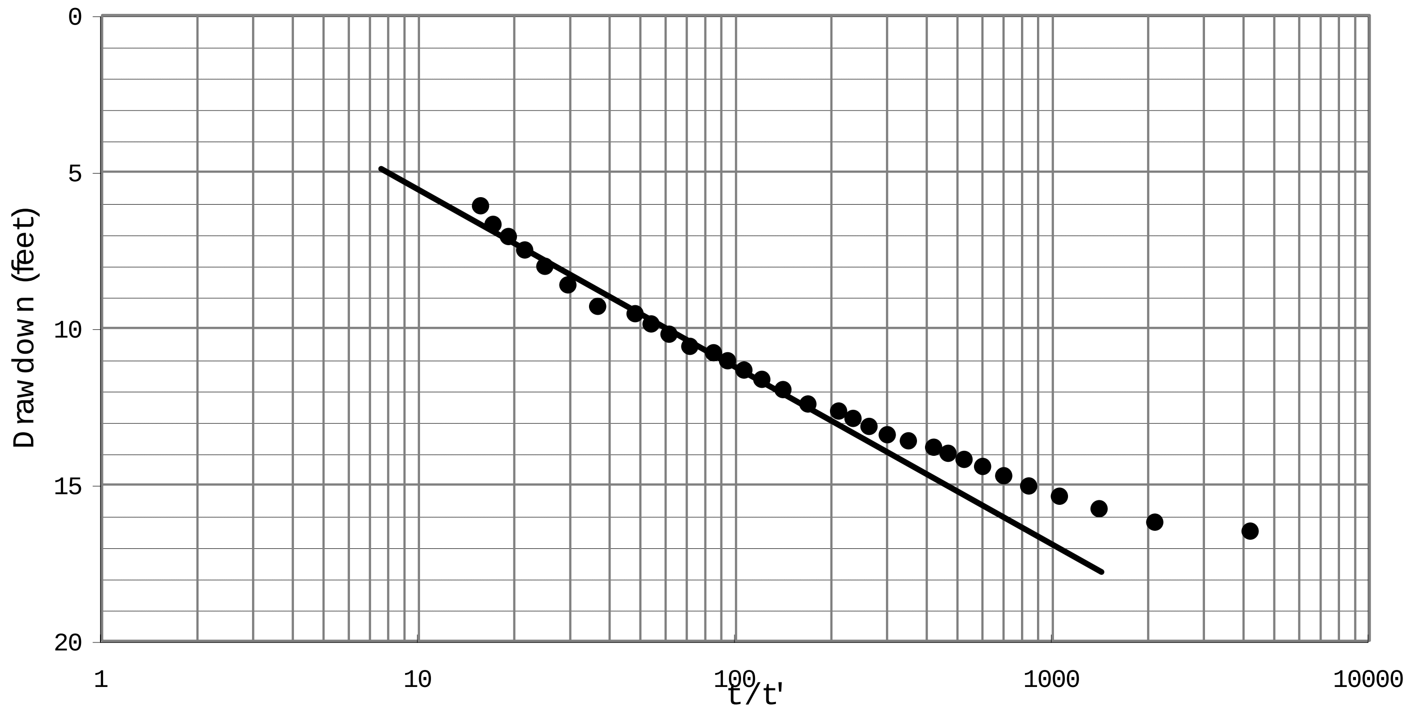

t= time since pumping started (min)
t'= time since pumping ended (min)
Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(900)/(6.0)
T ~ 39,600 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BCVI-4	Figure B-18 THEIS RECOVERY PLOT

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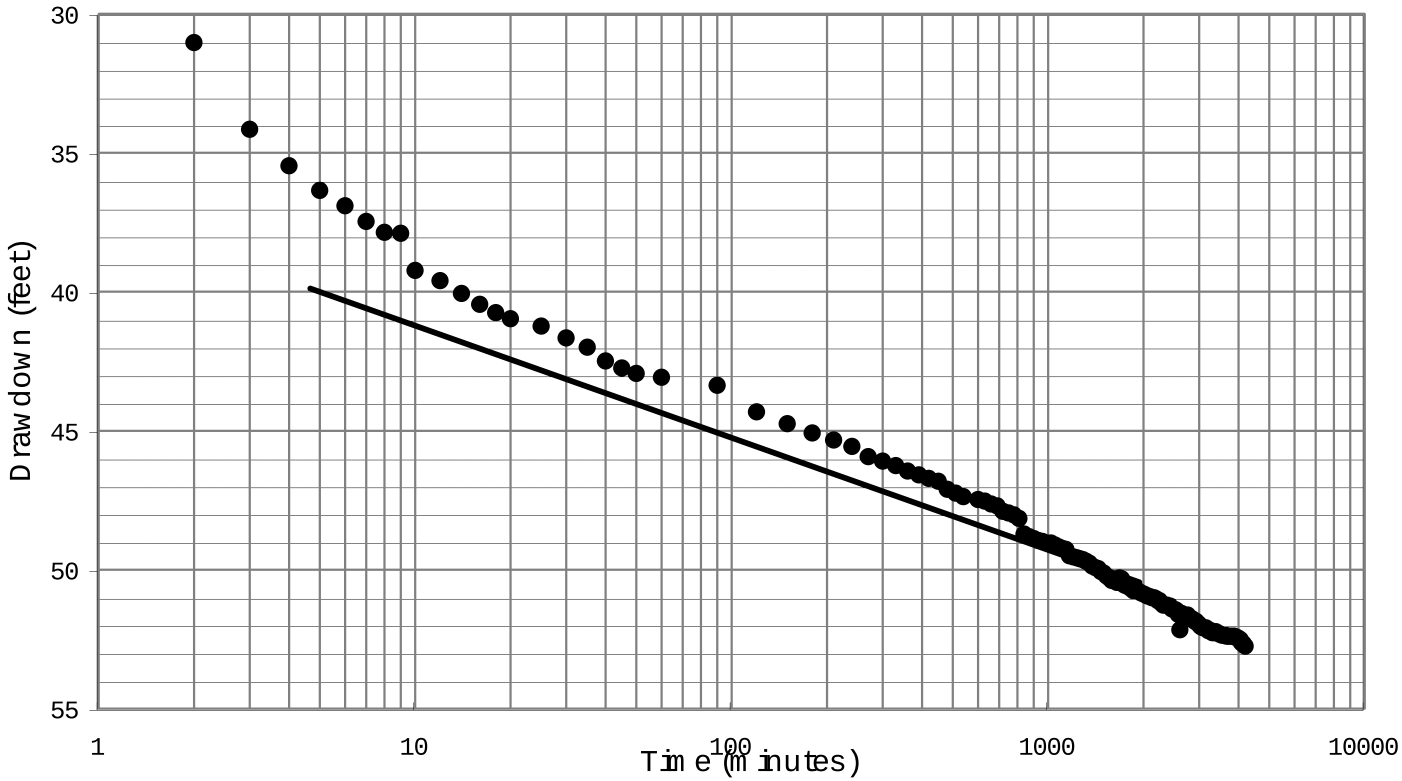
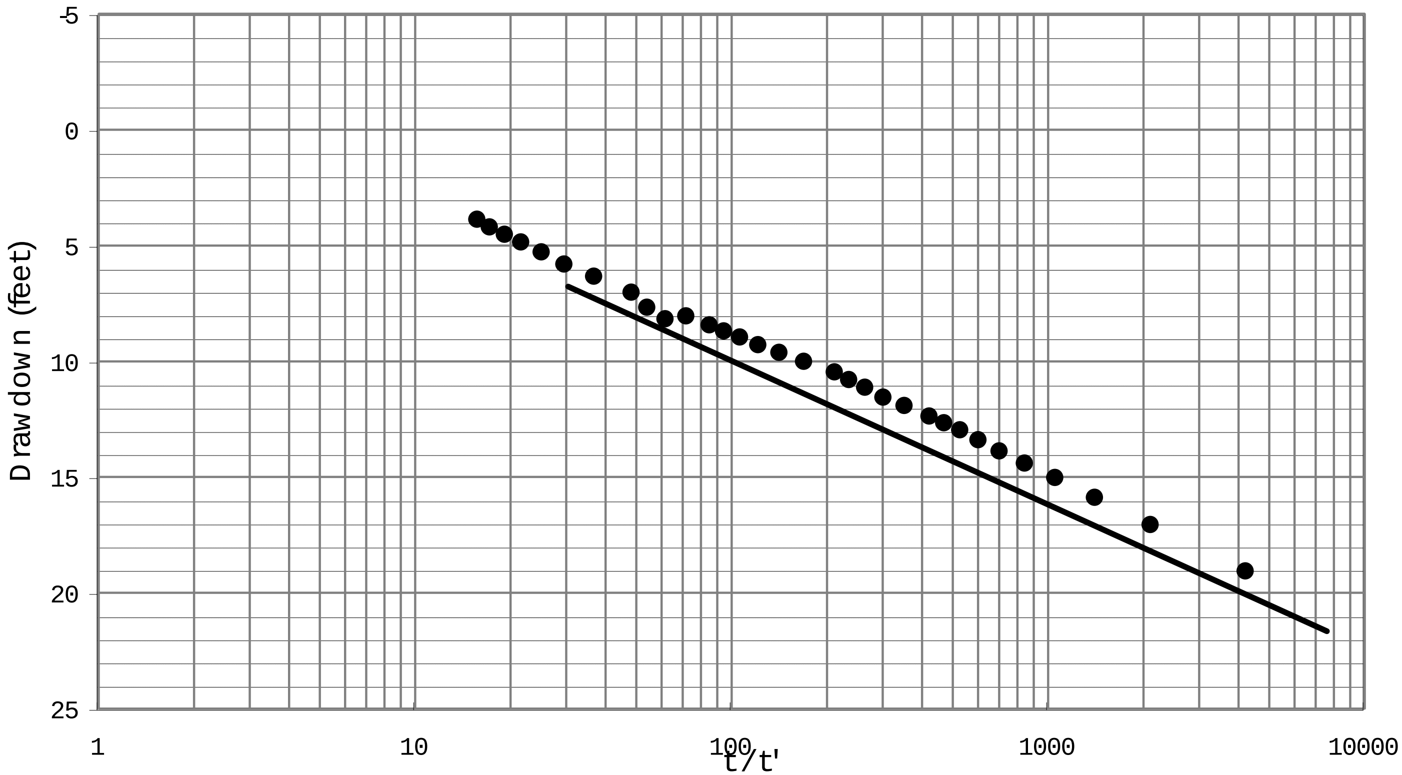


Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(900)/(6.15)
T ~ 38,600 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BCVI-5	Figure B-19 COOPER-JACOB PLOT



t = time since pumping started (min)
t' = time since pumping ended (min)
Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(900)/(6.5)
T ~ 35,500 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BCVI-5	Figure B-20 THEIS RECOVERY PLOT

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draw-down at the end of the test was approximately 17 m (20 m bgs) (55 feet (66 ft bgs)). Specific capacities measured during the step-rate test ranged between approximately 22.5 to 18.3 gpm/ft. The constant-rate test at BCVI-5 commenced on January 17, 2002. The test well was pumped at an average rate of approximately 900 gpm for seven hours. Prior to the constant-rate discharge test, measured static water levels in wells BCVI-4 and BCVI-5 were approximately 5.2 and 4.6 m (17 and 15 ft) bgs, respectively. At the conclusion of the test, total measured groundwater draw-downs in BCVI-4 and BCVI-5 were 5 and 16 m, respectively (10 and 21 m bgs) (17 and 53 feet respectively (34 and 68 ft bgs)). The calculated specific capacity of the test well is approximately 17.0 gpm/ft. After the pump test was complete, recovery water levels were recorded. After five hours, water levels recovered 63 percent in BCVI-4 and 93 percent in BCVI-5. Analysis of the constant-rate discharge test data estimates transmissivity of the aquifer at this site to be between 35,500 and 41,000 gallons per day per foot (gpd/ft). Analysis of draw-down in the monitor well indicates the storage coefficient (the volume of water released from storage, per unit change in hydraulic gradient) to be 0.0003.

Table B-7. Summary of Constant Rate Discharge Tests

Name of Well	BCVI-2	BCVI-3	BCVI-4	BCVI-5
Transmissivity Estimated from Drawdown (gpd/ft)	9,100	9,800	41,000	38,600
Transmissivity Estimated from Recovery (gpd/ft)	7,900	7,800	39,600	35,500
Storage Coefficient	not available from pumping well data	0.0012	0.0003	not available from pumping well data
Date Started	8/16/2001	8/16/2001	1/17/2002	1/17/2002
Date Ended	8/19/2001	8/19/2001	1/20/2002	1/20/2002
Duration (hours)	70.5	70.5	70	70
Depth of Pump (ft, bgs)	~200	not available for observation well	not available for observation well	~140
Pump Rate (gpm)	372			900
Specific Capacity (gpm/ft)	8.2			17.0
Static Water Level (ft, bgs)	46.43	46.42	16.67	14.67

Note: A constant rate test was not conducted at BCVI-1 due to the low specific capacity of the well measured during the step rate test.
gpd=gallons per day
gpm=gallons per minute
ft=feet
bgs=below ground surface

9.0 WATER QUALITY SAMPLING

A sample of groundwater was collected from each new project well either at the end of the well development or at the end of the step-rate discharge test. Water quality samples were also collected from specific pre-existing wells that comprise the groundwater monitoring network established by Brown and Caldwell for Villanueva. Water quality samples were collected from Villa Sol, Villa Linda, Cañeras II, Manuel Coello, Pintala I, La Victoria, and Guadalupe Lopez. This sampling was conducted in support of the water quality component of the Honduras Groundwater Monitoring Study and analytical results are included in Table B-8 as well as the laboratory reports at the end of this appendix.

Each well was sampled for general chemistry constituents that included, but were not limited to, acidity, alkalinity, total hardness, bicarbonate (expressed as $CaCO_3$), calcium, magnesium, manganese, phosphates, sulfates, nitrates and nitrites, sodium, and potassium. Each well was also sampled for a limited number of heavy metals including antimony, arsenic, lead, mercury, selenium, cadmium, chromium, nickel, silver, and zinc. In addition, most wells were analyzed for the presence of total and fecal coliform to assess the amount of fecal matter from untreated wastewater or range and other domestic animals infiltrating from the surface to the groundwater. Additionally, some of the wells were analyzed for other chemical constituents (chosen on an individual well basis) and included volatile organic compounds (VOCs), pesticides, herbicides, and radiological indicators such as gross a and gross ß.

In general, the location of the well provided the main criteria for establishing the list of analytes to be analyzed. For example, a well located in the cañeras was selected for the analyses of pesticides and herbicides to assess whether the chemicals used to deter insects and rodents from the crops were infiltrating to the groundwater supply. Similarly, for wells that were located in the vicinity of a factory was selected for the analyses of VOCs to determine the presence or absence of organic chemicals being released to the groundwater supply.

The groundwater sampling procedure for all wells included field water quality measurements (pH, temperature, and conductivity) to confirm that pumped groundwater was representative of aquifer pore water. Samples were collected in containers supplied by Jordan Laboratories of San Pedro Sula and Southern Petroleum Laboratory (SPL) of Houston, Texas. Samples were immediately labeled and placed on ice in laboratory-supplied coolers. Samples for general chemistry and bacteriological analysis were shipped via overnight or same-day service to Jordan Laboratories in San Pedro Sula. Samples for metals, pesticides and herbicides, PCB and VOC analysis were shipped to SPL in Houston. Proper chain-of-custody documentation was filled out and accompanied collected samples to the laboratory.

The water quality sample for BCVI-1 was collected on September 14, 2001 during the step-rate discharge test. The water quality sample for BCVI-2 was collected on September 16, 2001 during the step-rate discharge test. The sample for observation well BCVI-4 was collected after letting the water run for one hour on November 8, 2001 and the sample for BCVI-5 was collected during the step-rate discharge test conducted on January 19, 2002.

The groundwater sample from well BCVI-1 was submitted for selected general chemistry constituents, VOCs, herbicides, pesticides, and metals. No VOCs, herbicides or pesticides were detected. The only metals detected were arsenic (0.00827 milligrams per liter (mg/L)) and zinc (0.231 mg/L). While these concentrations exceed the detection limit capabilities of the laboratory, they fall below the acceptable guidelines established by the World Health Organization (WHO). The WHO guidelines for arsenic and zinc are 0.01 mg/L and 3 mg/L, respectively (WHO, 1996). Other elevated concentrations reported at BCVI-1 include conductivity (823 μS/cm) and potassium (10.8 mg/L). The current WHO guidelines do not address conductivity (reported as total dissolved solids (TDS)) or potassium. In addition to the following elevated concentrations, fecal and total coliform were reported at 2 UFC/100 ml and 32 UFC/ml indicating that infiltration of fecal matter in this area may be an issue that needs to be addressed in future treatment planning.

Test well BCVI-2 was sampled for general chemistry constituents, fecal and total coliform, selected heavy metals, pesticides, herbicides and polychlorinated biphenyls. With the exception of elevated concentrations of arsenic (0.021 mg/L) and zinc, (0.0745 mg/L), none of the other constituents were detected by the laboratory. The WHO guideline for arsenic in groundwater is 0.01 mg/L (WHO, 1996). Concentrations at BCVI-2 exceed this guideline. This concentration may represent an area of elevated background levels, possibly due to the presence of volcanic rocks, which contain natural concentrations of arsenic. The reported level for zinc at BCVI-2 falls within WHO guidelines for safe drinking-water.

Observation well BCVI-3 was not sampled due to its close proximity to test well BCVI-2.

Observation well BCVI-4 and associated test well BCVI-5 were analyzed for general chemistry parameters, metals, and pesticides. Conductivity measurements at BCVI-4 were reported at 794 μS/cm, and at BCVI-5 the level was reported at 671 μS/cm. Fecal and total coliform were not detected at these well locations. Concentrations of the metals included in this sampling were reported below the minimum detection capabilities of the laboratory.

The remaining samples collected from municipal wells were analyzed for concentrations of heavy metals and general chemistry constituents. In addition, some of the samples were analyzed for concentrations of total and fecal coliform. Conductivity measurements ranged from 632 μs/cm (approximately 380 mg/L TDS) at well Pintala 1 to 915 μs/cm (approximately 570 mg/L TDS) at well Villa Sol. TDS is proportional to electrical conductance, with conductance being about 1.6 times greater than TDS concentrations. Normal drinking water has a TDS range of 300 to 800 mg/L. Seawater has a TDS of approximately 32,000 mg/L. The recommended limit for TDS by the WHO is 500 mg/L, with a maximum of 1,500 mg/L (WHO, 1996). Concentrations of arsenic over the drinking water standard were reported in well Guadalupe Lopez (0.0257 mg/L), and near the standard in well Villa Linda (0.00894 mg/L).

Concentrations of nitrate were reported in wells Cañeras No. 2 (11.5 mg/L), Guadalupe Lopez (1.81 mg/L), La Victoria (19.84 mg/L), Manuel Coello (5 mg/L), Pintala 1 (6 mg/L), Villa Linda Norte (1) (1.81 mg/L), and Villasol 11 (22.2 mg/L). The WHO standard for nitrate in drinking-water is 50 mg/L (WHO, 1996). Continued groundwater monitoring of these areas is strongly suggested to determine whether nitrate levels are increasing or decreasing. Overall, coliform concentrations were low, with the highest concentration collected from well La Victoria at 48 UFC/100 ml for total coliform and 23 UFC/100 ml for fecal coliform. While these concentrations are considered low, they may be indicative of sanitation disposal in the area, an issue that may require attention for future groundwater treatment planning.

10.0 REFERENCES

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Table B-8. Well Analytical Results
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Analytical Constituent	Unit	Analytical Method: Method 1	Analytical Method: Method 2	Result	WHO Guideline (health based)
Well BCVI-1					
General Chemistry					
Acidez Total	mg/l	2310-B		37.97	-
Alcalinidad Total	mg/l CaCO3	2320-B		339.27	-
Bicarbonato (HCO3)	mg/l	2320-B		339	-
Dureza Total	mg/l CaCO3	2340-C		251	-
Conductividad	ms/cm	25100-B		823	-
Calcio	mg/l CaCO3	3500-Ca D		56	-
Hierro Total	mg/l	3500-Fe-D		0.09	0.3
Magnesio	mg/l CaCO3	3500-Mg E		27	50
Manganeso Total	mg/l	3500-Mn C		<0.03	0.5
Cloruros	mg/l	4500-Cl-B		29	250
Nitritos	mg/l	4500-NO2-B		0.06	1
Nitratos	mg/l	4500-NO3-B		1.5	50
Sulfatos	mg/l	4500-SO4		24	250
Potasio (K)	mg/l	AA		10.8	10
Sodio (Na)	mg/l	AA		85	200
Coliformes Totales	UFC/100 ml	9222-B		32	0
Coliformes Fecales	UFC/100 ml	9222-D		2	0
Metals					
Antimony	mg/l	6010B	3005	<0.005	0.005
Arsenic	mg/l	6010B	3005	0.00827	0.01
Cadmium	mg/l	6010B	3005	<0.005	0.003
Chromium	mg/l	6010B	3005	<0.01	0.05
Lead	mg/l	6010B	3005	<0.005	0.01
Nickel	mg/l	6010B	3005	<0.02	0.02
Selenium	mg/l	6010B	3005	<0.005	0.01
Silver	mg/l	6010B	3005	<0.01	-
Zinc	mg/l	6010B	3005	0.231	3
Mercury	mg/l	7470A	7470A	<0.002	0.001
Pesticides					
4,4'-DDD	mg/l	8081	3510B	<0.01	-
4,4'-DDE	mg/l	8081	3510B	<0.01	-
4,4'-DDT	mg/l	8081	3510B	<0.01	2
Aldrin	mg/l	8081	3510B	<0.05	0.03
alpha-BHC	mg/l	8081	3510B	<0.05	-
alpha-Chlordane	mg/l	8081	3510B	<0.05	-
beta-BHC	mg/l	8081	3510B	<0.05	-
Chlordane	mg/l	8081	3510B	<0.05	0.2
delta-BHC	mg/l	8081	3510B	<0.05	-
Dieldrin	mg/l	8081	3510B	<0.1	-
Endosulfan I	mg/l	8081	3510B	<0.05	-
Endosulfan II	mg/l	8081	3510B	<0.1	-
Endosulfan Sulfate	mg/l	8081	3510B	<0.1	-
Endrin	mg/l	8081	3510B	<0.1	-
Endrin aldehyde	mg/l	8081	3510B	<0.1	-
Endrin ketone	mg/l	8081	3510B	<0.1	-
gamma-BHC	mg/l	8081	3510B	<0.05	-
gamma-Chlordane	mg/l	8081	3510B	<0.05	-
Heptachlor	mg/l	8081	3510B	<0.05	0.03

Table B-8. Well Analytical Results

Analytical Constituent	Unit	Analytical Method		Result	WHO Guideline (health based)
		Method 1	Method 2		
Well BCVI-1 (continued)					
Heptachlor epoxide	mg/l	8081	3510B	<0.05	0.03
Methoxychlor	mg/l	8081	3510B	<0.5	20
Toxaphene	mg/l	8081	3510B	<1	-
Herbicides					
2,4,5-T	mg/l	8151A	SW 3510B	<1	9
2,4,5-TP (Silvex)	mg/l	8151A	SW 3510B	<1	-
2,4-D	mg/l	8151A	SW 3510B	<1	30
2,4-DB	mg/l	8151A	SW 3510B	<1	90
Dalapon	mg/l	8151A	SW 3510B	<1	-
Dicamba	mg/l	8151A	SW 3510B	<1	-
Dichloroprop	mg/l	8151A	SW 3510B	<1	100
Dinoseb	mg/l	8151A	SW 3510B	<1	-
MCPA	mg/l	8151A	SW 3510B	<25	2
MCPP	mg/l	8151A	SW 3510B	<25	-
Volatile Organics					
1,1,1,2-Tetrachloroethane	mg/l	8260B		<5	-
1,1,1-Trichloroethane	mg/l	8260B		<5	2000
1,1,2,2-Tetrachloroethane	mg/l	8260B		<5	-
1,1,2-Trichloroethane	mg/l	8260B		<5	-
1,1-Dichloroethane	mg/l	8260B		<5	-
1,1-Dichloroethene	mg/l	8260B		<5	30
1,1-Dichloropropene	mg/l	8260B		<5	-
1,2,3-Trichlorobenzene	mg/l	8260B		<5	-
1,2,3-Trichloropropane	mg/l	8260B		<5	-
1,2,4-Trichlorobenzene	mg/l	8260B		<5	-
1,2,4-Trimethylbenzene	mg/l	8260B		<5	-
1,2-Dibromo-3-chloropropane	mg/l	8260B		<5	1
1,2-Dibromoethane	mg/l	8260B		<5	0.4-15
1,2-Dichlorobenzene	mg/l	8260B		<5	1,000
1,2-Dichloroethane	mg/l	8260B		<5	30
1,2-Dichloroethene (total)	mg/l	8260B		<5	50
1,2-Dichloropropane	mg/l	8260B		<5	40
1,3,5-Trimethylbenzene	mg/l	8260B		<5	-
1,3-Dichlorobenzene	mg/l	8260B		<5	-
1,3-Dichloropropane	mg/l	8260B		<5	-
1,4-Dichlorobenzene	mg/l	8260B		<5	300
2,2-Dichloropropane	mg/l	8260B		<5	-
2-Butanone	mg/l	8260B		<20	-
2-Chloroethylvinylether	mg/l	8260B		<10	-
2-Chlorotoluene	mg/l	8260B		<5	-
2-Hexanone	mg/l	8260B		<10	-
4-Chlorotoluene	mg/l	8260B		<5	-
4-Isopropyltoluene	mg/l	8260B		<5	-
4-Methyl-2-pentanone	mg/l	8260B		<10	-
Acetone	mg/l	8260B		<100	-
Acrylonitrile	mg/l	8260B		<50	-
Benzene	mg/l	8260B		<5	10
Bromobenzene	mg/l	8260B		<5	-
Bromochloromethane	mg/l	8260B		<5	-

Table B-8. Well Analytical Results

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Analytical Constituent	Unit	Analytical Method		Result	WHO Guideline (health based)
		Method 1	Method 2		
Well BCVI-1 (continued)					
Bromodichloromethane	mg/l	8260B		<5	60
Bromoform	mg/l	8260B		<5	100
Bromomethane	mg/l	8260B		<10	-
Carbon disulfide	mg/l	8260B		<5	-
Carbon tetrachloride	mg/l	8260B		<5	2
Chlorobenzene	mg/l	8260B		<5	-
Chloroethane	mg/l	8260B		<10	-
Chloroform	mg/l	8260B		<5	200
Chloromethane	mg/l	8260B		<10	-
cis-1,2-Dichloroethene	mg/l	8260B		<5	-
cis-1,3-Dichloropropene	mg/l	8260B		<5	-
Dibromochloromethane	mg/l	8260B		<5	100
Dibromomethane	mg/l	8260B		<5	-
Dichlorodifluoromethane	mg/l	8260B		<10	300
Ethylbenzene	mg/l	8260B		<5	0.6
Hexachlorobutadiene	mg/l	8260B		<5	-
Isopropylbenzene	mg/l	8260B		<5	-
m,p-Xylene	mg/l	8260B		<5	-
Methyl tert-butyl ether	mg/l	8260B		<5	-
Methylene chloride	mg/l	8260B		<5	-
Naphthalene	mg/l	8260B		<5	-
n-Butylbenzene	mg/l	8260B		<5	-
n-Propylbenzene	mg/l	8260B		<5	-
o-Xylene	mg/l	8260B		<5	-
sec-Butylbenzene	mg/l	8260B		<5	-
Styrene	mg/l	8260B		<5	20
tert-Butylbenzene	mg/l	8260B		<5	-
Tetrachloroethene	mg/l	8260B		<5	40
Toluene	mg/l	8260B		<5	700
trans-1,2-Dichloroethene	mg/l	8260B		<5	-
trans-1,3-Dichloropropene	mg/l	8260B		<5	-
Trichloroethene	mg/l	8260B		<5	70
Trichlorofluoromethane	mg/l	8260B		<5	-
Vinyl acetate	mg/l	8260B		<10	-
Vinyl chloride	mg/l	8260B		<10	5
Xylenes, Total	mg/l	8260B		<5	500
Coliformes Totales	UFC/100 ml	9222-B		32	0
Coliformes Fecales	UFC/100 ml	9222-D		2	0
Potasio (K)	mg/l	AA		10.8	10
Sodio (Na)	mg/l	AA		85	200
Well BCVI-2					
General Chemistry					
Acidez Total	mg/l	2310-B		36	-
Alcalinidad Total	mg/l CaCO3	2320-B		383	-
Dureza Total	mg/l CaCO3	2340-C		192	-
Potasio	mg/l	2340-C		12.81	-
Conductividad	ms/cm	25100-B		960	-
Calcio	mg/l CaCO3	3500-Ca D		42.4	-
Hierro Total	mg/l	3500-Fe-D		0.03	0.3

Table B-8. Well Analytical Results
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Analytical Constituent	Unit	Analytical Method		Result	WHO Guideline (health based)
		Method 1	Method 2		
Well BCVI-2 (continued)					
Magnesio	mg/l CaCO3	3500-Mg E		20.64	50
Manganeso Total	mg/l	3500-Mn C		<0.03	0.1
Sodio (Na)	mg/l	3500-Na C		131.21	200
Cloruros	mg/l	4500-Cl-B		58.5	250
Nitritos	mg/l	4500-NO2-B		<0.01	1
Nitratos	mg/l	4500-NO3-B		0	50
Sulfatos	mg/l	4500-SO4		25.7	250
Metals					-
Antimony	mg/l	6010B	3005	<0.005	0.005
Arsenic	mg/l	6010B	3005	0.021	0.01
Cadmium	mg/l	6010B	3005	<0.005	0.03
Chromium	mg/l	6010B	3005	<0.01	0.05
Lead	mg/l	6010B	3005	<0.005	0.01
Nickel	mg/l	6010B	3005	<0.02	0.02
Selenium	mg/l	6010B	3005	<0.005	0.01
Silver	mg/l	6010B	3005	<0.01	-
Zinc	mg/l	6010B	3005	0.0745	3
Mercury	mg/l	7470A	7470A	<0.0002	1
Pesticides					
4,4'-DDD	mg/l	8081	3510B	<0.1	-
4,4'-DDE	mg/l	8081	3510B	<0.1	-
4,4'-DDT	mg/l	8081	3510B	<0.1	2
Aldrin	mg/l	8081	3510B	<0.05	0.03
alpha-BHC	mg/l	8081	3510B	<0.05	-
alpha-Chlordane	mg/l	8081	3510B	<0.05	-
beta-BHC	mg/l	8081	3510B	<0.05	-
Chlordane	mg/l	8081	3510B	<0.05	0.2
delta-BHC	mg/l	8081	3510B	<0.05	-
Dieldrin	mg/l	8081	3510B	<0.1	-
Endosulfan I	mg/l	8081	3510B	<0.05	-
Endosulfan II	mg/l	8081	3510B	<0.1	-
Endosulfan Sulfate	mg/l	8081	3510B	<0.1	-
Endrin	mg/l	8081	3510B	<0.1	-
Endrin aldehyde	mg/l	8081	3510B	<0.1	-
Endrin ketone	mg/l	8081	3510B	<0.1	-
gamma-BHC	mg/l	8081	3510B	<0.05	-
gamma-Chlordane	mg/l	8081	3510B	<0.05	-
Heptachlor	mg/l	8081	3510B	<0.05	0.03
Heptachlor epoxide	mg/l	8081	3510B	<0.05	0.03
Methoxychlor	mg/l	8081	3510B	<0.5	20
Toxaphene	mg/l	8081	3510B	<1	-
Aroclor 1016	mg/l	8082	3510B	0	-
Aroclor 1221	mg/l	8082	3510B	0	-
Aroclor 1232	mg/l	8082	3510B	0	-
Aroclor 1242	mg/l	8082	3510B	0	-
Aroclor 1248	mg/l	8082	3510B	0	-
Aroclor 1254	mg/l	8082	3510B	0	-
Aroclor 1260	mg/l	8082	3510B	0	-

Table B-8. Well Analytical Results

Analytical Constituent	Unit	Analytical Method		Result	WHO Guideline
		Method 1	Method 2		(health based)
Well BCVI-2 (continued)					
Herbicides					
2,4,5-TP (Silvex)	mg/l	8151A	SW 3510B	<1	9
2,4-D	mg/l	8151A	SW 3510B	<1	-
2,4-DB	mg/l	8151A	SW 3510B	<1	30
Dalapon	mg/l	8151A	SW 3510B	<1	90
Dicamba	mg/l	8151A	SW 3510B	<1	-
Dichloroprop	mg/l	8151A	SW 3510B	<1	-
Dinoseb	mg/l	8151A	SW 3510B	<1	100
MCPA	mg/l	8151A	SW 3510B	<25	-
MCPP	mg/l	8151A	SW 3510B	<25	2
Bacteriology					
Coliformes Totales	UFC/100 ml	9222-B		0	0
Coliformes Fecales	UFC/100 ml	9222-D		0	0
Bicarbonato al HCO3	mg/l			383	-
Well BCVI-4					
Metals					
Antimony	mg/l	6010B	3005	<0.005	0.005
Arsenic	mg/l	6010B	3005	<0.005	0.01
Cadmium	mg/l	6010B	3005	<0.005	0.003
Chromium	mg/l	6010B	3005	<0.01	0.005
Lead	mg/l	6010B	3005	<0.005	0.01
Nickel	mg/l	6010B	3005	<0.02	0.02
Selenium	mg/l	6010B	3005	<0.005	0.01
Silver	mg/l	6010B	3005	<0.01	-
Zinc	mg/l	6010B	3005	<0.02	3
Mercury	mg/l	7470A	7470A	<0.0002	0.001
Bacteriology					
Coliformes Totales	UFC/100 ml	9222-B		0	0
Coliformes Fecales	UFC/100 ml	9222-D		0	0
Well Cañeras no 2					
General Chemistry					
Acidez Total	mg/l	2310-B		68	-
Alcalinidad Total	mg/l CaCO3	2320-B		332	-
Bicarbonato (HCO3)	mg/l	2320-B		332	-
Dureza Total	mg/l CaCO3	2340-C		312	-
Conductividad	ms/cm	25100-B		668	-
Calcio	mg/l CaCO3	3500-Ca D		84	-
Hierro Filtrado	mg/l	3500-Fe-D		<0.03	-
Hierro Total	mg/l	3500-Fe-D		<0.03	0.3
Magnesio	mg/l CaCO3	3500-Mg E		24	50
Manganeso Filtrado	mg/l	3500-Mn C		0	-
Manganeso Total	mg/l	3500-Mn C		<0.03	0.5
Cloruros	mg/l	4500-Cl-B		34	250
Nitritos	mg/l	4500-NO2-B		<0.01	1
Nitratos	mg/l	4500-NO3-B		11.5	50
Sulfatos	mg/l	4500-SO4		58	250
Metals					-
Antimony	mg/l	6010B	3005	<0.005	0.005
Arsenic	mg/l	6010B	3005	<0.005	0.01

Table B-8. Well Analytical Results

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Analytical Constituent	Unit	Analytical Method		Result	WHO Guideline
		Method 1	Method 2		(health based)
Well Cañeras no 2 (continued)					
Cadmium	mg/l	6010B	3005	<0.005	0.003
Chromium	mg/l	6010B	3005	<0.01	0.05
Lead	mg/l	6010B	3005	<0.005	0.01
Nickel	mg/l	6010B	3005	<0.02	0.02
Selenium	mg/l	6010B	3005	<0.005	0.01
Silver	mg/l	6010B	3005	<0.01	-
Zinc	mg/l	6010B	3005	<0.02	3
Mercury	mg/l	7470A	7470A	<0.0002	0.001
Pesticides					
4,4'-DDD	mg/l	8081	3510B	<0.1	-
4,4'-DDE	mg/l	8081	3510B	<0.1	-
4,4'-DDT	mg/l	8081	3510B	<0.1	2
Aldrin	mg/l	8081	3510B	<0.05	0.03
alpha-BHC	mg/l	8081	3510B	<0.05	-
alpha-Chlordane	mg/l	8081	3510B	<0.05	-
beta-BHC	mg/l	8081	3510B	<0.05	-
Chlordane	mg/l	8081	3510B	<0.5	0.2
delta-BHC	mg/l	8081	3510B	<0.05	-
Dieldrin	mg/l	8081	3510B	<0.1	-
Endosulfan I	mg/l	8081	3510B	<0.05	-
Endosulfan II	mg/l	8081	3510B	<0.1	-
Endosulfan Sulfate	mg/l	8081	3510B	<0.1	-
Endrin	mg/l	8081	3510B	<0.1	-
Endrin aldehyde	mg/l	8081	3510B	<0.1	-
Endrin ketone	mg/l	8081	3510B	<0.1	-
gamma-BHC	mg/l	8081	3510B	<0.05	-
gamma-Chlordane	mg/l	8081	3510B	<0.05	-
Heptachlor	mg/l	8081	3510B	<0.05	0.03
Heptachlor epoxide	mg/l	8081	3510B	<0.05	0.03
Methoxychlor	mg/l	8081	3510B	<0.5	20
Toxaphene	mg/l	8081	3510B	<1	-
Herbicides					
2,4,5-T	mg/l	8151A	SW 3510B	<1	9
2,4,5-TP (Silvex)	mg/l	8151A	SW 3510B	<1	-
2,4-D	mg/l	8151A	SW 3510B	<1	30
2,4-DB	mg/l	8151A	SW 3510B	<1	90
Dalapon	mg/l	8151A	SW 3510B	<1	-
Dicamba	mg/l	8151A	SW 3510B	<1	-
Dichloroprop	mg/l	8151A	SW 3510B	<1	100
Dinoseb	mg/l	8151A	SW 3510B	<1	-
MCPA	mg/l	8151A	SW 3510B	<25	2
MCPP	mg/l	8151A	SW 3510B	<25	-
Bacteriology					
Coliformes Totales	UFC/100ml	9222-B		0	0
Coliformes Fecales	UFC/100ml	9222-D		0	0
Potasio (K)	mg/l	AA		3.46	10
Sodio (Na)	mg/l	AA		41.15	20

Table B-8. Well Analytical Results
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Analytical Constituent	Unit	Analytical Method		Result	WHO Guideline (health based)
		Method 1	Method 2		
Well Guadalupe Lopez					
General Chemistry					
Acidez Total	mg/l	2310-B		49	-
Acidez Total	mg/l	2310-B		85	-
Alcalinidad Total	mg/l CaCO3	2320-B		372	-
Bicarbonato (HCO3)	mg/l	2320-B		372	-
Alcalinidad Total	mg/l CaCO3	2320-B		375	-
Bicarbonato (HCO3)	mg/l	2320-B		375	-
Dureza Total	mg/l CaCO3	2340-C		196	-
Conductividad	ms/cm	25100-B		859	-
Conductividad	ms/cm	25100-B		890	-
Calcio	mg/l CaCO3	3500-Ca D		56	-
Calcio	mg/l CaCO3	3500-Ca D		55	-
Hierro Filtrado	mg/l	3500-Fe-D		0	-
Hierro Total	mg/l	3500-Fe-D		<0.03	0.3
Magnesio	mg/l CaCO3	3500-Mg E		13	50
Magnesio	mg/l CaCO3	3500-Mg E		14	50
Manganeso Filtrado	mg/l	3500-Mn C		0	-
Manganeso Total	mg/l	3500-Mn C		<0.03	0.5
Cloruros	mg/l	4500-Cl-B		59	250
Cloruros	mg/l	4500-Cl-B		69	250
pH		4500-H-B		6.88	-
pH		4500-H-B		7	-
Nitritos	mg/l	4500-NO2-B		<0.01	1
Nitratos	mg/l	4500-NO3-B		1.81	50
Nitratos	mg/l	4500-NO3-B		2	50
Sulfatos	mg/l	4500-SO4		45	250
Metals					-
Antimony	mg/l	6010B	3005	<0.005	0.005
Arsenic	mg/l	6010B	3005	0.0266	0.01
Cadmium	mg/l	6010B	3005	<0.005	0.003
Chromium	mg/l	6010B	3005	<0.01	0.05
Lead	mg/l	6010B	3005	<0.005	0.01
Nickel	mg/l	6010B	3005	<0.02	0.02
Selenium	mg/l	6010B	3005	<0.005	0.01
Silver	mg/l	6010B	3005	<0.01	-
Zinc	mg/l	6010B	3005	<0.02	3
Mercury	mg/l	7470A	7470A	<0.0002	0.001
Bacteriology					-
Coliformes Totales	UFC/100ml	9222-B		0	0
Coliformes Fecales	UFC/100ml	9222-D		0	0

Table B-8. Well Analytical Results

Analytical Constituent	Unit	Analytical Method		Result	WHO Guideline (health based)
		Method 1	Method 2		
Well Guadalupe Lopez (continued)					
Potasio (K)	mg/l	AA		8.26	10
Sodio (Na)	mg/l	AA		126.8	200
Potasio (K)	mg/l	AA		10.28	10
Sodio (Na)	mg/l	AA		130.05	200
Well La Victoria					
General Chemistry					
Acidez Total	mg/l	2310-B		74	-
Alcalinidad Total	mg/l CaCO3	2320-B		370	-
Bicarbonato (HCO3)	mg/l	2320-B		370	-
Dureza Total	mg/l CaCO3	2340-C		388	-
Conductividad	ms/cm	25100-B		797	-
Calcio	mg/l CaCO3	3500-Ca D		114	-
Hierro Filtrado	mg/l	3500-Fe-D		0	-
Hierro Total	mg/l	3500-Fe-D		0.09	0.3
Magnesio	mg/l CaCO3	3500-Mg E		24	50
Manganeso Filtrado	mg/l	3500-Mn C		0	-
Manganeso Total	mg/l	3500-Mn C		<0.03	0.5
Cloruros	mg/l	4500-Cl-B		53	250
Nitritos	mg/l	4500-NO2-B		<0.01	1
Nitratos	mg/l	4500-NO3-B		19.84	50
Sulfatos	mg/l	4500-SO4		28	250
Bacteriology					
Coliformes Totales	UFC/100 ml	9222-B		48	0
Coliformes Fecales	UFC/100 ml	9222-D		23	0
Potasio (K)	mg/l	AA		3.64	10
Sodio (Na)	mg/l	AA		32.5	200
Well Manuel Coello					
General Chemistry					
Acidez Total	mg/l	2310-B		78	-
Alcalinidad Total	mg/l CaCO3	2320-B		380	-
Bicarbonato (HCO3)	mg/l	2320-B		380	-
Dureza Total	mg/l CaCO3	2340-C		308	-
Conductividad	ms/cm	25100-B		668	-
Calcio	mg/l CaCO3	3500-Ca D		91	-
Hierro Filtrado	mg/l	3500-Fe-D		0	-
Hierro Total	mg/l	3500-Fe-D		<0.03	0.3
Magnesio	mg/l CaCO3	3500-Mg E		19	50
Manganeso Filtrado	mg/l	3500-Mn C		0	-
Manganeso Total	mg/l	3500-Mn C		<0.03	0.5
Cloruros	mg/l	4500-Cl-B		29	250
Nitritos	mg/l	4500-NO2-B		<0.01	1
Nitratos	mg/l	4500-NO3-B		5	50
Sulfatos	mg/l	4500-SO4		18	250
Metals					-
Antimony	mg/l	6010B	3005	<0.005	0.005
Arsenic	mg/l	6010B	3005	<0.005	0.01
Cadmium	mg/l	6010B	3005	<0.005	0.003
Chromium	mg/l	6010B	3005	<0.01	0.05

Table B-8. Well Analytical Results

(Page 9 of 11)

Analytical Constituent	Unit	Analytical Method		Result	WHO Guideline (health based)
		Method 1	Method 2		
Well Manuel Coello (continued)					
Lead	mg/l	6010B	3005	<0.005	0.01
Nickel	mg/l	6010B	3005	<0.02	0.02
Selenium	mg/l	6010B	3005	<0.005	0.01
Silver	mg/l	6010B	3005	<0.01	-
Zinc	mg/l	6010B	3005	<0.02	3
Mercury	mg/l	7470A	7470A	<0.002	0.001
Bacteriology					
Coliformes Totales	UFC/100 ml	9222-B		1	0
Coliformes Fecales	UFC/100 ml	9222-D		0	0
Potasio (K)	mg/l	AA		4.27	10
Sodio (Na)	mg/l	AA		42.8	200
Well Pintala I					
General Chemistry					
Acidez Total	mg/l	2310-B		62	-
Alcalinidad Total	mg/l CaCO3	2320-B		342	-
Bicarbonato (HCO3)	mg/l	2320-B		342	-
Dureza Total	mg/l CaCO3	2340-C		308	-
Conductividad	ms/cm	25100-B		632	-
Calcio	mg/l CaCO3	3500-Ca D		67	-
Hierro Filtrado	mg/l	3500-Fe-D		0	-
Hierro Total	mg/l	3500-Fe-D		<0.03	0.3
Magnesio	mg/l CaCO3	3500-Mg E		34	50
Manganeso Filtrado	mg/l	3500-Mn C		0	-
Manganeso Total	mg/l	3500-Mn C		<0.03	0.5
Cloruros	mg/l	4500-Cl-B		23	250
Nitritos	mg/l	4500-NO2-B		<0.01	1
Nitratos	mg/l	4500-NO3-B		6	50
Sulfatos	mg/l	4500-SO4		62	250
Metals					
Antimony	mg/l	6010B	3005	<0.005	0.005
Arsenic	mg/l	6010B	3005	<0.005	0.01
Cadmium	mg/l	6010B	3005	<0.005	0.003
Chromium	mg/l	6010B	3005	<0.01	0.05
Lead	mg/l	6010B	3005	<0.005	0.01
Nickel	mg/l	6010B	3005	<0.02	0.02
Selenium	mg/l	6010B	3005	<0.005	0.01
Silver	mg/l	6010B	3005	<0.01	-
Zinc	mg/l	6010B	3005	<0.02	3
Mercury	mg/l	7470A	7470A	<0.002	0.001
Bacteriology					
Coliformes Totales	UFC/100 ml	9222-B		11	0
Coliformes Fecales	UFC/100 ml	9222-D		0	0
Potasio (K)	mg/l	AA		3.6	10
Sodio (Na)	mg/l	AA		47.75	200
Well Villa Linda Norte (I)					
General Chemistry					
Acidez Total	mg/l	2310-B		73	-
Alcalinidad Total	mg/l CaCO3	2320-B		362	-
Bicarbonato (HCO3)	mg/l	2320-B		362	-

Table B-8. Well Analytical Results

Analytical Constituent	Unit	Analytical Method: Method 1	Analytical Method: Method 2	Result	WHO Guideline (health based)
Well Villa Linda Norte (I) (continued)					
Dureza Total	mg/l CaCO3	2340-C		308	-
Conductividad	ms/cm	25100-B		715	-
Calcio	mg/l CaCO3	3500-Ca D		94	-
Hierro Filtrado	mg/l	3500-Fe-D		0	-
Hierro Total	mg/l	3500-Fe-D		<0.03	0.3
Magnesio	mg/l CaCO3	3500-Mg E		17	50
Manganeso Filtrado	mg/l	3500-Mn C		0	-
Manganeso Total	mg/l	3500-Mn C		<0.03	0.5
Cloruros	mg/l	4500-Cl-B		43	250
Nitritos	mg/l	4500-NO2-B		<0.01	1
Nitratos	mg/l	4500-NO3-B		1.81	50
Sulfatos	mg/l	4500-SO4		58	250
Metals					
Antimony	mg/l	6010B	3005	<0.005	0.005
Arsenic	mg/l	6010B	3005	0.00694	0.01
Cadmium	mg/l	6010B	3005	<0.005	0.003
Chromium	mg/l	6010B	3005	<0.01	0.05
Lead	mg/l	6010B	3005	<0.005	0.01
Nickel	mg/l	6010B	3005	<0.02	0.02
Selenium	mg/l	6010B	3005	<0.005	0.01
Silver	mg/l	6010B	3005	<0.01	-
Zinc	mg/l	6010B	3005	<0.02	3
Mercury	mg/l	7470A	7470A	<0.002	0.001
Bacteriology					
Coliformes Totales	UFC/100 ml	9222-B		11	0
Coliformes Fecales	UFC/100 ml	9222-D		0	0
Potasio (K)	mg/l	AA		6.09	10
Sodio (Na)	mg/l	AA		47.1	200
Well Villasol					
General Chemistry					
Acidez Total	mg/l	2310-B		52	-
Alcalinidad Total	mg/l CaCO3	2320-B		357	-
Bicarbonato (HCO3)	mg/l	2320-B		357	-
Dureza Total	mg/l CaCO3	2340-C		376	-
Conductividad	ms/cm	25100-B		915	-
Calcio	mg/l CaCO3	3500-Ca D		75	-
Hierro Filtrado	mg/l	3500-Fe-D		0	-
Hierro Total	mg/l	3500-Fe-D		<0.03	0.3
Magnesio	mg/l CaCO3	3500-Mg E		45	50
Manganeso Filtrado	mg/l	3500-Mn C		0	-
Manganeso Total	mg/l	3500-Mn C		<0.03	0.5
Cloruros	mg/l	4500-Cl-B		39	250
Nitritos	mg/l	4500-NO2-B		<0.01	1
Nitratos	mg/l	4500-NO3-B		22.2	50
Sulfatos	mg/l	4500-SO4		61.2	250
Metals					
Antimony	mg/l	6010B	3005	<0.005	0.005
Arsenic	mg/l	6010B	3005	<0.005	0.01
Cadmium	mg/l	6010B	3005	<0.005	0.003

Table B-8. Well Analytical Results

Analytical Constituent	Unit	Analytical Method		Result	WHO Guideline (health based)
		Method 1	Method 2		
Well Villasol (continued)					
Chromium	mg/l	6010B	3005	<0.01	0.05
Lead	mg/l	6010B	3005	<0.005	0.01
Nickel	mg/l	6010B	3005	<0.02	0.02
Selenium	mg/l	6010B	3005	<0.005	0.01
Silver	mg/l	6010B	3005	<0.01	-
Zinc	mg/l	6010B	3005	<0.02	3
Mercury	mg/l	7470A	7470A	<0.002	0.001
Bacteriology					
Coliformes Totales	UFC/100 ml	9222-B		40	0
Coliformes Fecales	UFC/100 ml	9222-D		4	0
Potasio (K)	mg/l	AA		4.98	10
Sodio (Na)	mg/l	AA		34.8	200

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BC-V1-1 **Collected:** 9/14/01 6:15:00 **SPL Sample ID:** 01090636-01

Site: **Villanueva, Honduras**

Analyses/Method	Result		Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORINATED HERBICIDES BY METHOD 8151A				**MCL**	**SW8151A**		**Units: ug/L**		
2,4,5-T	ND		1		1		10/03/01 8:19	SG	849468
2,4,5-TP (Silvex)	ND		1		1		10/03/01 8:19	SG	849468
2,4-D	ND		1		1		10/03/01 8:19	SG	849468
2,4-DB	ND		1		1		10/03/01 8:19	SG	849468
Dalapon	ND		1		1		10/03/01 8:19	SG	849468
Dicamba	ND		1		1		10/03/01 8:19	SG	849468
Dichloroprop	ND		1		1		10/03/01 8:19	SG	849468
Dinoseb	ND		1		1		10/03/01 8:19	SG	849468
MCPA	ND		25		1		10/03/01 8:19	SG	849468
MCPP	ND		25		1		10/03/01 8:19	SG	849468
Surr: DCAA	98.2	%	19-162		1		10/03/01 8:19	SG	849468

Prep Method	Prep Date	Prep Initials
SW3510B	09/20/2001 16:53	J_L

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		09/26/01 11:55	R_T	843228

Prep Method	Prep Date	Prep Initials
SW7470A	09/26/2001 9:35	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		10/01/01 18:17	NS	848129
Arsenic	0.00827	0.005		1		10/01/01 18:17	NS	848129
Lead	ND	0.005		1		10/01/01 18:17	NS	848129
Selenium	ND	0.005		1		10/01/01 18:17	NS	848129
Cadmium	ND	0.005		1		09/23/01 20:17	EG	839819
Chromium	ND	0.01		1		09/23/01 20:17	EG	839819
Nickel	ND	0.02		1		09/23/01 20:17	EG	839819
Silver	ND	0.01		1		09/23/01 20:17	EG	839819
Zinc	0.231	0.02		1		09/23/01 20:17	EG	839819

Prep Method	Prep Date	Prep Initials
SW3005	09/21/2001 7:30	MW

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BC-V1-1 **Collected:** 9/14/01 6:15:00 **SPL Sample ID:** 01090636-01

Site: **Villanueva, Honduras**

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
ORGANOCHLORINE PESTICIDES BY METHOD 8081A			**MCL**	**SW8081**		**Units: ug/L**		
4,4´-DDD	ND		0.1	1		09/29/01 4:05	SG	846006
4,4´-DDE	ND		0.1	1		09/29/01 4:05	SG	846006
4,4´-DDT	ND		0.1	1		09/29/01 4:05	SG	846006
Aldrin	ND		0.05	1		09/29/01 4:05	SG	846006
alpha-BHC	ND		0.05	1		09/29/01 4:05	SG	846006
alpha-Chlordane	ND		0.05	1		09/29/01 4:05	SG	846006
beta-BHC	ND		0.05	1		09/29/01 4:05	SG	846006
Chlordane	ND		0.5	1		09/29/01 4:05	SG	846006
delta-BHC	ND		0.05	1		09/29/01 4:05	SG	846006
Dieldrin	ND		0.1	1		09/29/01 4:05	SG	846006
Endosulfan I	ND		0.05	1		09/29/01 4:05	SG	846006
Endosulfan II	ND		0.1	1		09/29/01 4:05	SG	846006
Endosulfan sulfate	ND		0.1	1		09/29/01 4:05	SG	846006
Endrin	ND		0.1	1		09/29/01 4:05	SG	846006
Endrin aldehyde	ND		0.1	1		09/29/01 4:05	SG	846006
Endrin ketone	ND		0.1	1		09/29/01 4:05	SG	846006
gamma-BHC	ND		0.05	1		09/29/01 4:05	SG	846006
gamma-Chlordane	ND		0.05	1		09/29/01 4:05	SG	846006
Heptachlor	ND		0.05	1		09/29/01 4:05	SG	846006
Heptachlor epoxide	ND		0.05	1		09/29/01 4:05	SG	846006
Methoxychlor	ND		0.5	1		09/29/01 4:05	SG	846006
Toxaphene	ND		1	1		09/29/01 4:05	SG	846006
Surr: Decachlorobiphenyl	127	%	40-123	1	*	09/29/01 4:05	SG	846006
Surr: Tetrachloro-m-xylene	104	%	39-106	1		09/29/01 4:05	SG	846006

Prep Method	Prep Date	Prep Initials
SW3510B	09/20/2001 16:30	WV

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BC-V1-1 **Collected:** 9/14/01 6:15:00 **SPL Sample ID:** 01090636-01

Site: **Villanueva, Honduras**

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
VOLATILE ORGANICS BY METHOD 8260B		**MCL**	**SW8260B**		**Units: ug/L**		
1,1,1,2-Tetrachloroethane	ND	5	1		09/25/01 0:14	JC	840676
1,1,1-Trichloroethane	ND	5	1		09/25/01 0:14	JC	840676
1,1,2,2-Tetrachloroethane	ND	5	1		09/25/01 0:14	JC	840676
1,1,2-Trichloroethane	ND	5	1		09/25/01 0:14	JC	840676
1,1-Dichloroethane	ND	5	1		09/25/01 0:14	JC	840676
1,1-Dichloroethene	ND	5	1		09/25/01 0:14	JC	840676
1,1-Dichloropropene	ND	5	1		09/25/01 0:14	JC	840676
1,2,3-Trichlorobenzene	ND	5	1		09/25/01 0:14	JC	840676
1,2,3-Trichloropropane	ND	5	1		09/25/01 0:14	JC	840676
1,2,4-Trichlorobenzene	ND	5	1		09/25/01 0:14	JC	840676
1,2,4-Trimethylbenzene	ND	5	1		09/25/01 0:14	JC	840676
1,2-Dibromo-3-chloropropane	ND	5	1		09/25/01 0:14	JC	840676
1,2-Dibromoethane	ND	5	1		09/25/01 0:14	JC	840676
1,2-Dichlorobenzene	ND	5	1		09/25/01 0:14	JC	840676
1,2-Dichloroethane	ND	5	1		09/25/01 0:14	JC	840676
1,2-Dichloropropane	ND	5	1		09/25/01 0:14	JC	840676
1,3,5-Trimethylbenzene	ND	5	1		09/25/01 0:14	JC	840676
1,3-Dichlorobenzene	ND	5	1		09/25/01 0:14	JC	840676
1,3-Dichloropropane	ND	5	1		09/25/01 0:14	JC	840676
1,4-Dichlorobenzene	ND	5	1		09/25/01 0:14	JC	840676
2,2-Dichloropropane	ND	5	1		09/25/01 0:14	JC	840676
2-Butanone	ND	20	1		09/25/01 0:14	JC	840676
2-Chloroethyl vinyl ether	ND	10	1		09/25/01 0:14	JC	840676
2-Chlorotoluene	ND	5	1		09/25/01 0:14	JC	840676
2-Hexanone	ND	10	1		09/25/01 0:14	JC	840676
4-Chlorotoluene	ND	5	1		09/25/01 0:14	JC	840676
4-Isopropyltoluene	ND	5	1		09/25/01 0:14	JC	840676
4-Methyl-2-pentanone	ND	10	1		09/25/01 0:14	JC	840676
Acetone	ND	100	1		09/25/01 0:14	JC	840676
Acrylonitrile	ND	50	1		09/25/01 0:14	JC	840676
Benzene	ND	5	1		09/25/01 0:14	JC	840676
Bromobenzene	ND	5	1		09/25/01 0:14	JC	840676
Bromochloromethane	ND	5	1		09/25/01 0:14	JC	840676
Bromodichloromethane	ND	5	1		09/25/01 0:14	JC	840676
Bromoform	ND	5	1		09/25/01 0:14	JC	840676
Bromomethane	ND	10	1		09/25/01 0:14	JC	840676
Carbon disulfide	ND	5	1		09/25/01 0:14	JC	840676
Carbon tetrachloride	ND	5	1		09/25/01 0:14	JC	840676
Chlorobenzene	ND	5	1		09/25/01 0:14	JC	840676
Chloroethane	ND	10	1		09/25/01 0:14	JC	840676

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BC-V1-1 **Collected:** 9/14/01 6:15:00 **SPL Sample ID:** 01090636-01

Site: Villanueva, Honduras

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
Chloroform	ND		5	1		09/25/01 0:14	JC	840676
Chloromethane	ND		10	1		09/25/01 0:14	JC	840676
cis-1,3-Dichloropropene	ND		5	1		09/25/01 0:14	JC	840676
Dibromochloromethane	ND		5	1		09/25/01 0:14	JC	840676
Dibromomethane	ND		5	1		09/25/01 0:14	JC	840676
Dichlorodifluoromethane	ND		10	1		09/25/01 0:14	JC	840676
Ethylbenzene	ND		5	1		09/25/01 0:14	JC	840676
Hexachlorobutadiene	ND		5	1		09/25/01 0:14	JC	840676
Isopropylbenzene	ND		5	1		09/25/01 0:14	JC	840676
Methyl tert-butyl ether	ND		5	1		09/25/01 0:14	JC	840676
Methylene chloride	ND		5	1		09/25/01 0:14	JC	840676
n-Butylbenzene	ND		5	1		09/25/01 0:14	JC	840676
n-Propylbenzene	ND		5	1		09/25/01 0:14	JC	840676
Naphthalene	ND		5	1		09/25/01 0:14	JC	840676
sec-Butylbenzene	ND		5	1		09/25/01 0:14	JC	840676
Styrene	ND		5	1		09/25/01 0:14	JC	840676
tert-Butylbenzene	ND		5	1		09/25/01 0:14	JC	840676
Tetrachloroethene	ND		5	1		09/25/01 0:14	JC	840676
Toluene	ND		5	1		09/25/01 0:14	JC	840676
trans-1,3-Dichloropropene	ND		5	1		09/25/01 0:14	JC	840676
Trichloroethene	ND		5	1		09/25/01 0:14	JC	840676
Trichlorofluoromethane	ND		5	1		09/25/01 0:14	JC	840676
Vinyl acetate	ND		10	1		09/25/01 0:14	JC	840676
Vinyl chloride	ND		10	1		09/25/01 0:14	JC	840676
cis-1,2-Dichloroethene	ND		5	1		09/25/01 0:14	JC	840676
m,p-Xylene	ND		5	1		09/25/01 0:14	JC	840676
o-Xylene	ND		5	1		09/25/01 0:14	JC	840676
trans-1,2-Dichloroethene	ND		5	1		09/25/01 0:14	JC	840676
1,2-Dichloroethene (total)	ND		5	1		09/25/01 0:14	JC	840676
Xylenes,Total	ND		5	1		09/25/01 0:14	JC	840676
Surr: 1,2-Dichloroethane-d4	100	%	62-130	1		09/25/01 0:14	JC	840676
Surr: 4-Bromofluorobenzene	104	%	70-130	1		09/25/01 0:14	JC	840676
Surr: Toluene-d8	100	%	74-122	1		09/25/01 0:14	JC	840676

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

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6 Ave. 5-6 Calle S.O. San Pedro Sula, Cortés
R. T. N. X4RRMA-U TELFAX: 557-5802, Email: jordanlab@hn2.com

BROWN AND CALDWELL

Solicitado por:Ing. Barbara Goodrich
Muestra # 1053, [redacted]
Fecha de Ingreso: 18/09/01

Parametros	Unidades	Norma Nacional Recomendado	Norma Nacional Max. Admisible	Metodo &	Resultados
Acidez Total	mg/l			2310-B	37.97
Conductividad	us/cm	400		25100-B	823
Alcalinidad Total	mg/l CaCO3			2320-B	339.27
Dureza Total	mg/l CaCO3	400		2340-C	251
Bicarbonato (HCO3)	mg/l			2320-B	339
Calcio	mg/l CaCO3	100		3500-Ca D	56
Magnesio	mg/l CaCO3	30	50	3500-Mg E	27
Hierro Total	mg/l		0.3	3500-Fe-D	0.09
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	<0.03
Cloruros	mg/l	25	250	4500-Cl-B	29
Sulfatos	mg/l	25	250	4500-SO4	24
Nitritos	mg/l		1	4500-NO2-B	0.06
Nitratos	mg/l	25	50	4500-NO3-B	1.50
Sodio (Na)*	mg/1	25	200	AA	85.00
Potasio (K)*	mg/l		10	AA	10.80

Norma Nacional: Decreto No.084 del 31de Julio de 1995
& Basados en Standard Methods for the Examination of Water and Wastewater 20 Edition.

*Subcontratado

San Pedro Sula, 25 de Septiembre del 2,001

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL

LIC. LILIA J. DE RIVERA
JORDANLAB

JORDANLAB
Laboratorio de Analisis Industrial
Agua Potable,Residual e Industrial Ambientes de Trabajo,Alimentos

6 Ave. 5-6 Calle S.O. San Pedro Sula, Cortés.
R.T.N. X4RRMA-U Tel/Fax: 557-5802, Tel: 557-2753, Email: jordanlab@hn2.com

BROWN AND CALDWELL

Solicitado por: Ing. Barbara Goodrish

A continuación detallo a Ud. el resultado de Análisis Microbiólogicos en Agua de Pozo.

Fecha de Ingreso: 31/08/01

Parametros	Valor Norma	Metodo	Resultados
Coliformes Totales	0 UFC/100 ml	9222-B	32
Coliformes Fecales	0 UFC/100 ml	9222-D	2

Standard Methods Examination of Water and Wastewater 20 Th Edition.

Descripción de Muestras	# de Ingreso
BC-VF-1, Vill[illegible]	1034

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LIC. LILIA J. DE RIVERA
JORDANLAB

San Pedro Sula, 3 de Septiembre del 2,001

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID: BCV1-2 **Collected:** 8/16/01 9:45:00 **SPL Sample ID:** 01080660-01

Site: **Villanueva,Honduras**

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORINATED HERBICIDES BY METHOD 8151A			**MCL**	**SW8151A**		**Units: ug/L**		
2,4,5-T	ND		1	1		08/21/01 22:40	SG	801956
2,4,5-TP (Silvex)	ND		1	1		08/21/01 22:40	SG	801956
2,4-D	ND		1	1		08/21/01 22:40	SG	801956
2,4-DB	ND		1	1		08/21/01 22:40	SG	801956
Dalapon	ND		1	1		08/21/01 22:40	SG	801956
Dicamba	ND		1	1		08/21/01 22:40	SG	801956
Dichloroprop	ND		1	1		08/21/01 22:40	SG	801956
Dinoseb	ND		1	1		08/21/01 22:40	SG	801956
MCPA	ND		25	1		08/21/01 22:40	SG	801956
MCPP	ND		25	1		08/21/01 22:40	SG	801956
Surr: DCAA	70.0	%	19-162	1		08/21/01 22:40	SG	801956

Prep Method	Prep Date	Prep Initials
SW3510B	08/21/2001 8:27	DB

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED		**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002	1		09/12/01 12:12	R_T	827302

Prep Method	Prep Date	Prep Initials
SW7470A	09/12/2001 9:20	R_T

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED		**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005	1		09/11/01 21:33	NS	827998
Arsenic	0.021	0.005	1		09/11/01 21:33	NS	827998
Lead	ND	0.005	1		09/11/01 21:33	NS	827998
Selenium	ND	0.005	1		09/11/01 21:33	NS	827998
Cadmium	ND	0.005	1		09/14/01 15:24	EG	830146
Chromium	ND	0.01	1		09/14/01 15:24	EG	830146
Nickel	ND	0.02	1		09/14/01 15:24	EG	830146
Silver	ND	0.01	1		09/14/01 15:24	EG	830146
Zinc	0.0745	0.02	1		09/14/01 15:24	EG	830146

Prep Method	Prep Date	Prep Initials
SW3005	09/10/2001 17:00	MME

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID: BCV1-2 **Collected:** 8/16/01 9:45:00 **SPL Sample ID:** 01080660-01

Site: Villanueva,Honduras

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
ORGANOCHLORINE PESTICIDES BY METHOD 8081A			**MCL**		**SW8081**	**Units: ug/L**		
4,4´-DDD	ND		0.1	1		08/28/01 14:03	SG	810024
4,4´-DDE	ND		0.1	1		08/28/01 14:03	SG	810024
4,4´-DDT	ND		0.1	1		08/28/01 14:03	SG	810024
Aldrin	ND		0.05	1		08/28/01 14:03	SG	810024
alpha-BHC	ND		0.05	1		08/28/01 14:03	SG	810024
alpha-Chlordane	ND		0.05	1		08/28/01 14:03	SG	810024
beta-BHC	ND		0.05	1		08/28/01 14:03	SG	810024
Chlordane	ND		0.5	1		08/28/01 14:03	SG	810024
delta-BHC	ND		0.05	1		08/28/01 14:03	SG	810024
Dieldrin	ND		0.1	1		08/28/01 14:03	SG	810024
Endosulfan I	ND		0.05	1		08/28/01 14:03	SG	810024
Endosulfan II	ND		0.1	1		08/28/01 14:03	SG	810024
Endosulfan sulfate	ND		0.1	1		08/28/01 14:03	SG	810024
Endrin	ND		0.1	1		08/28/01 14:03	SG	810024
Endrin aldehyde	ND		0.1	1		08/28/01 14:03	SG	810024
Endrin ketone	ND		0.1	1		08/28/01 14:03	SG	810024
gamma-BHC	ND		0.05	1		08/28/01 14:03	SG	810024
gamma-Chlordane	ND		0.05	1		08/28/01 14:03	SG	810024
Heptachlor	ND		0.05	1		08/28/01 14:03	SG	810024
Heptachlor epoxide	ND		0.05	1		08/28/01 14:03	SG	810024
Methoxychlor	ND		0.5	1		08/28/01 14:03	SG	810024
Toxaphene	ND		1	1		08/28/01 14:03	SG	810024
Surr: Decachlorobiphenyl	84.5	%	1-121	1		08/28/01 14:03	SG	810024
Surr: Tetrachloro-m-xylene	55.9	%	15-100	1		08/28/01 14:03	SG	810024

Prep Method	Prep Date	Prep Initials
SW3510B	08/22/2001 12:40	KL

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
POLYCHLORINATED BIPHENYLS BY METHOD 8082			**MCL**		**SW8082**	**Units: ug/L**		
Aroclor 1016	ND		1	1		08/23/01 23:20	AR	804924
Aroclor 1221	ND		1	1		08/23/01 23:20	AR	804924
Aroclor 1232	ND		1	1		08/23/01 23:20	AR	804924
Aroclor 1242	ND		1	1		08/23/01 23:20	AR	804924
Aroclor 1248	ND		1	1		08/23/01 23:20	AR	804924
Aroclor 1254	ND		1	1		08/23/01 23:20	AR	804924
Aroclor 1260	ND		1	1		08/23/01 23:20	AR	804924
Surr: Tetrachloro-m-xylene	56.2	%	30-112	1		08/23/01 23:20	AR	804924
Surr: Decachlorobiphenyl	72.6	%	2-152	1		08/23/01 23:20	AR	804924

Prep Method	Prep Date	Prep Initials
SW3510B	08/22/2001 12:45	KL

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

ACCULABS INC. GOLDEN, CO
RADIOCHEMISTRY DATA PACKAGE
SAMPLE RESULTS SUMMARY
FORM 1

Client: SPL, Inc.
Proj. Name:
Proj. Number: 095995

Acculabs Work Order: G01090510
Received Date: 09/20/2001

Field Sample ID	Acculabs ID	Test	Matrix	Analyte	Result +/- CSU	MDC	Report Units	Report Basis	Qual Flag	Date Analyzed	Batch Id
01080660-01A	G01090510-01A	Gross Alpha/Beta	Aqueous	Alpha	9.1 +/- 3.8	3.9	pCi/L	total		10/22/2001	GP00083
01080660-01A	G01090510-01A	Gross Alpha/Beta	Aqueous	Beta	10.8 +/- 2.8	3.2	pCi/L	total		10/22/2001	GP00083

Comments:

Footnotes and Abbreviations:

MDC - Minimum Detectable Concentration (ANSI N42.23)
CSU - Combined Standard Uncertainty (TPU)

Lab Qualifiers:

U = Result < MDC or CSU
J = Estimated result - see narrative for discussion
B = analyte detected in Blank > MDC
JI = Estimated result, bias high due to interference
M = Requested MDC not met - see narrative for discussion
Y = Yield outside default limits
H = High
L = Low
* = DER outside 2 sigma limits

Queried: 10/25/2001 01:24:02 PM
Printed: 10/25/2001 01:24:02 PM

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Laboratorio de Analisis Industrial

Agua Potable,Residual e Industrial Ambientes de Trabajo,Alimentos

6 Ave. 5-6 Calle S.O. San Pedro Sula, Cortés
R. T. N. X4RRMA-U TELFAX: 557-5802, Email: jordanlab@hn2.com

BROWN AND CALDWEL

Solicitado por: Barbara Goodrich

Muestra # 963, Agua de Pozo, BCVI-2, Hora:9:45 FQ, 9:50 MB

Lugar: Villanueva, Cortes

Fecha Toma de Muestra: 17/08/01

Muestra Tomada por: Cliente

		Norma Nacional			
	Unidades	Recomendado	Máx. Admisible	Método	Resultado
Conductividad	us/cm	400		25100-B	960
Alcalinidad Total	mg/l CaCO3			2320-B	383
Calcio	mg/l CaCO3	100		3500-Ca D	42.4
Acidez Total	mg/l			2310-B	36
Dureza Total	mg/l CaCO3	400		2340-C	192
Magnesio	mg/l CaCO3	30	50	3500-Mg-E	20.64
Hierro Total	mg/l		0.3	3500-Fe-D	0.03
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	<0.03
Sodio	mg/l	25	200	3500-Na C	131.21
Potasio	mg/l		10	2340-C	12.81
Cloruros	mg/l	25	250	4500-Cl-B	58.5
Sulfatos	mg/l	25	250	4500-SO4	25.7
Nitritos	mg/l		1	4500-NO2-B	<0.01
Nitratos	mg/l	25	50	4500-NO3-B	<0.01
Bicarbonato al HCO_3^-	mg/l				383
ANALISIS MICROBIOLOICOS					
Coliformes Totales		UFC/100ml	0	9222-B	0
Coliformes Fecales		UFC/100ml	0	9222-D	0

Norma Nacional: Decreto No.084 del 31de Julio de 1995

& Basados en Standard Methods for the Examination of Water and Wastewater 20 Edition.

19

San Pedro Sula, ~~13~~ de Agosto del 2,001

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HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID: BC-V1-4 **Collected:** 11/8/01 10:30:00 **SPL Sample ID:** 01110476-07

Site: **Choluteca, Honduras**

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		11/20/01 14:10	R_T	926168

Prep Method	Prep Date	Prep Initials
SW7470A	11/20/2001 9:30	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		11/28/01 4:08	NS	926880
Arsenic	ND	0.005		1		11/26/01 22:05	NS	926029
Lead	ND	0.005		1		11/26/01 22:05	NS	926029
Selenium	ND	0.005		1		11/26/01 22:05	NS	926029
Cadmium	ND	0.005		1		11/25/01 20:02	EG	925371
Chromium	ND	0.01		1		11/25/01 20:02	EG	925371
Nickel	ND	0.02		1		11/25/01 20:02	EG	925371
Silver	ND	0.01		1		11/25/01 20:02	EG	925371
Zinc	ND	0.02		1		11/25/01 20:02	EG	925371

Prep Method	Prep Date	Prep Initials
SW3005	11/15/2001 9:30	MW

No CoC

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

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6 Ave. 5-6 Calle S.O. San Pedro Sula, Cortés
R. T. N. X4RRMA-U TELFAX: 557-5802, Email: jordanlab@hn2.com

BROWN AND CALDWELL

Solicitado por:Ing. Barbara Goodrish
Muestra # 1222, BC-VI- 4,Villanueva, Cañeras
Fecha Toma de Muestra :8/11/01, Hora: 10:30am
Fecha de Ingreso: 8/11/01

	Norma Nacional				
Parametros	Unidades	Recomendado	Máx. Admisibl	Metodo &	Resultados
Acidez Total	mg/l			2310-B	36
Conductividad	us/cm	400		25100-B	794
Alcalinidad Total	mg/l CaCO3			2320-B	284
Dureza Total	mg/l CaCO3	400		2340-C	188
Bicarbonato (HCO3)	mg/l			2320-B	284
Calcio	mg/l CaCO3	100		3500-Ca D	48
Magnesio	mg/l CaCO3	30	50	3500-Mg E	29
Hierro Total	mg/l		0.3	3500-Fe-D	<0.03
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	0.45
Cloruros	mg/l	25	250	4500-Cl-B	26
Sulfatos	mg/l	25	250	4500-SO4	66
Nitritos	mg/l		1	4500-NO2-B	<0.01
Nitratos	mg/l	25	50	4500-NO3-B	0.11
Sodio (Na)*	mg/1	25	200	AA	81.0
Potasio (K)*	mg/l		10	AA	8.70
ANALISIS MICROBIOLOGICOS					
Coliformes Totales		UFC/100ml	0	9222-B	0
Coliformes Fecales		UFC/100ml	0	9222-D	0

Norma Nacional: Decreto No.084 del 31de Julio de 1995
& Basados en Standard Methods for the Examination of Water and Wastewater 20 Edition.

*Subcontratado

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL

LILIA J. DE RIVERA
JORDANLAB

San Pedro Sula, 13 de Noviembre del 2,001

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6 Ave. 5-6 Calle S.O. San Pedro Sula,Cortés
R.T.N. X4RRMA-U TELFAX: 557-5802, 557-2753 Email: jordanlab@hn2.com

BROWN AND CALDWELL

Solicitado por: Ing. Barbara Goodrich
A continuación detallo a Ud. el resultado de Análisis Microbiológicos en Agua.

Fecha de Ingreso:25/09/01
Muestra: ~~BC-VI-4 Makeup~~

Parametros	Valor Norma	Metodo	1066
Coliformes Totales	0 UFC/100 ml	9222-B	0
Coliformes Fecales	0 UFC/100 ml	9222-D	0

Standard Methods Examination of Water and Watewater 20 Th Edition.

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LIC. LILIA J. DE RIVERA
JORDANLAB

San Pedro Sula, 28 de Septiembre del 2,001

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BC-V1-5 **Collected:** 1/17/02 2:30:00 **SPL Sample ID:** 02010709-01

Site: Villanueva, Honduras

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORINATED HERBICIDES BY METHOD 8151A			**MCL**	**SW8151A**		**Units: ug/L**		
2,4,5-T	ND		1	1		01/25/02 1:44	SG	994074
2,4,5-TP (Silvex)	ND		1	1		01/25/02 1:44	SG	994074
2,4-D	ND		1	1		01/25/02 1:44	SG	994074
2,4-DB	ND		1	1		01/25/02 1:44	SG	994074
Dalapon	ND		1	1		01/25/02 1:44	SG	994074
Dicamba	ND		1	1		01/25/02 1:44	SG	994074
Dichloroprop	ND		1	1		01/25/02 1:44	SG	994074
Dinoseb	ND		1	1		01/25/02 1:44	SG	994074
MCPA	ND		20	1		01/25/02 1:44	SG	994074
MCPP	ND		20	1		01/25/02 1:44	SG	994074
Surr: DCAA	140	%	19-162	1		01/25/02 1:44	SG	994074

Prep Method	Prep Date	Prep Initials
SW3510B	01/23/2002 16:31	J_L

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED		**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005	1		01/25/02 15:47	JS	994753
Arsenic	ND	0.005	1		01/25/02 15:47	JS	994753
Lead	ND	0.005	1		01/25/02 15:47	JS	994753
Selenium	ND	0.005	1		01/25/02 15:47	JS	994753
Cadmium	ND	0.005	1		01/24/02 16:03	NS	994233
Chromium	ND	0.01	1		01/24/02 16:03	NS	994233
Nickel	ND	0.02	1		01/24/02 16:03	NS	994233
Silver	ND	0.01	1		01/24/02 16:03	NS	994233
Zinc	ND	0.02	1		01/24/02 16:03	NS	994233

Prep Method	Prep Date	Prep Initials
SW3005A	01/23/2002 17:00	MME

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BC-V1-5 **Collected:** 1/17/02 2:30:00 **SPL Sample ID:** 02010709-01

Site: Villanueva, Honduras

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
ORGANOCHLORINE PESTICIDES BY METHOD 8081A			**MCL**	**SW8081**		**Units: ug/L**		
4,4´-DDD	ND		0.1	1		01/25/02 11:05	SG	994260
4,4´-DDE	ND		0.1	1		01/25/02 11:05	SG	994260
4,4´-DDT	ND		0.1	1		01/25/02 11:05	SG	994260
Aldrin	ND		0.05	1		01/25/02 11:05	SG	994260
alpha-BHC	ND		0.05	1		01/25/02 11:05	SG	994260
alpha-Chlordane	ND		0.05	1		01/25/02 11:05	SG	994260
beta-BHC	ND		0.05	1		01/25/02 11:05	SG	994260
Chlordane	ND		0.5	1		01/25/02 11:05	SG	994260
delta-BHC	ND		0.05	1		01/25/02 11:05	SG	994260
Dieldrin	ND		0.1	1		01/25/02 11:05	SG	994260
Endosulfan I	ND		0.05	1		01/25/02 11:05	SG	994260
Endosulfan II	ND		0.1	1		01/25/02 11:05	SG	994260
Endosulfan sulfate	ND		0.1	1		01/25/02 11:05	SG	994260
Endrin	ND		0.1	1		01/25/02 11:05	SG	994260
Endrin aldehyde	ND		0.1	1		01/25/02 11:05	SG	994260
Endrin ketone	ND		0.1	1		01/25/02 11:05	SG	994260
gamma-BHC	ND		0.05	1		01/25/02 11:05	SG	994260
gamma-Chlordane	ND		0.05	1		01/25/02 11:05	SG	994260
Heptachlor	ND		0.05	1		01/25/02 11:05	SG	994260
Heptachlor epoxide	ND		0.05	1		01/25/02 11:05	SG	994260
Methoxychlor	ND		0.5	1		01/25/02 11:05	SG	994260
Toxaphene	ND		1	1		01/25/02 11:05	SG	994260
Surr: Decachlorobiphenyl	110	%	40-150	1		01/25/02 11:05	SG	994260
Surr: Tetrachloro-m-xylene	79	%	39-106	1		01/25/02 11:05	SG	994260

Prep Method	Prep Date	Prep Initials
SW3510B	01/24/2002 9:47	G_T

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

JORDANLAB
Laboratorio de Analisis Industrial
Agua Potable,Residual e Industrial Ambientes de Trabajo,Alimentos

6 Ave. 5-6 Calle S.O. San Pedro Sula, Cortés
R. T. N. X4RRMA-U TELFAX: 557-5802, Email: jordanlab@hn2.com

BROWN AND CALDWELL

Solicitado por: Ing. Barbara Goodrich
Fecha de Ingreso: 12/11/01
Lugar Toma de Muestras: Choluteca

	Norma Nacional								
				Fecha	12/11/2001	12/11/2001	12/11/2001	12/11/2001	12/11/2001
				Hora	15:00	14:10		11:30	01:12
				Muestra	Villa Linda	Cañeras	Manuel Coello	Pintala	La Victoria
Parametros	Unidades	Recomen.	Max. Adm.	Metodo &	1238	1234	1235	1236	1237
Acidez Total	mg/l			2310-B	73	68	78	62	74
Conductividad	us/cm	400		25100-B	715	668	668	632	797
Alcalinidad Total	mg/l CaCO3			2320-B	362	332	380	342	370
Dureza Total	mg/l CaCO3	400		2340-C	308	312	308	308	388
Bicarbonato (HCO3)	mg/l			2320-B	362	332	380	342	370
Calcio	mg/l CaCO3	100		3500-Ca-D	94	84	91	67	114
Magnesio	mg/l CaCO3	30	50	3500-Mg E	17	24	19	·34	24
Hierro Total	mg/l		0.3	3500-Fe D	<0.03	<0.03	<0.03	<0.03	0.09
Hierro Filtrado	mg/l			3500-Fe D	<0.03	<0.03	<0.03	<0.03	<0.03
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	<0.03	<0.03	<0.03	<0.03	<0.03
Manganeso Filtrado	mg/l			3500-Mn C	<0.03	<0.03	<0.03	<0.03	<0.03
Cloruros	mg/l	25	250	4500-Cl-B	43	34	29	23	53
Sulfatos	mg/l	25	250	4500-SO4	58	58	18	62	28
Nitritos	mg/l		1	4500-NO2-B	<0.01	<0.01	<0.01	<0.01	<0.01
Nitratos	mg/l	25	50	4500-NO3-B	1.81	11.50	5.00	6.00	19.84
Sodio (Na)*	mg/l	25	200	AA	47.1	41.15	42.8	47.75	32.5
Potasio (K)*	mg/l		10	AA	6.09	3.46	4.27	3.6	3.64
ANALISIS MICROBIOLOGICOS									
Coliformes Totales		UFC/100ml	0	9222-B	11	0	1	11	48
Coliformes Fecales		UFC/100ml	0	9222-D	0	0	0	0	23

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL

LIC. LIDIA J. DE RIVERA
JORDANLAB

San Pedro Sula, 21 de Noviembre del 2001

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Caneras II 112001 **Collected:** 11/12/01 2:10:00 **SPL Sample ID:** 01110644-04

Site: **USAID Groundwater 21365**

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORINATED HERBICIDES BY METHOD 8151A			**MCL**	**SW8151A**		**Units: ug/L**		
2,4,5-T	ND		1	1		11/21/01 1:55	SG	919644
2,4,5-TP (Silvex)	ND		1	1		11/21/01 1:55	SG	919644
2,4-D	ND		1	1		11/21/01 1:55	SG	919644
2,4-DB	ND		1	1		11/21/01 1:55	SG	919644
Dalapon	ND		1	1		11/21/01 1:55	SG	919644
Dicamba	ND		1	1		11/21/01 1:55	SG	919644
Dichloroprop	ND		1	1		11/21/01 1:55	SG	919644
Dinoseb	ND		1	1		11/21/01 1:55	SG	919644
MCPA	ND		25	1		11/21/01 1:55	SG	919644
MCPP	ND		25	1		11/21/01 1:55	SG	919644
Surr: DCAA	80.3	%	19-162	1		11/21/01 1:55	SG	919644

Prep Method	Prep Date	Prep Initials
SW3510B	11/16/2001 11:13	DB

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED		**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002	1		11/28/01 12:59	R_T	932132

Prep Method	Prep Date	Prep Initials
SW7470A	11/28/2001 8:45	R_T

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED		**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005	1		11/27/01 5:15	NS	927019
Arsenic	ND	0.005	1		11/27/01 12:37	NS	927070
Lead	ND	0.005	1		11/27/01 5:15	NS	927019
Selenium	ND	0.005	1		11/27/01 5:15	NS	927019
Cadmium	ND	0.005	1		11/25/01 14:45	EG	925316
Chromium	ND	0.01	1		11/25/01 14:45	EG	925316
Nickel	ND	0.02	1		11/25/01 14:45	EG	925316
Silver	ND	0.01	1		11/25/01 14:45	EG	925316
Zinc	ND	0.02	1		11/25/01 14:45	EG	925316

Prep Method	Prep Date	Prep Initials
SW3005	11/16/2001 14:30	MME

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Caneras II 112001 **Collected:** 11/12/01 2:10:00 **SPL Sample ID:** 01110644-04

Site: USAID Groundwater 21365

Analyses/Method	Result		Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
ORGANOCHLORINE PESTICIDES BY METHOD 8081A				**MCL**		**SW8081**	**Units: ug/L**		
4,4´-DDD	ND		0.1		1		11/26/01 23:44	SG	924101
4,4´-DDE	ND		0.1		1		11/26/01 23:44	SG	924101
4,4´-DDT	ND		0.1		1		11/26/01 23:44	SG	924101
Aldrin	ND		0.05		1		11/26/01 23:44	SG	924101
alpha-BHC	ND		0.05		1		11/26/01 23:44	SG	924101
alpha-Chlordane	ND		0.05		1		11/26/01 23:44	SG	924101
beta-BHC	ND		0.05		1		11/26/01 23:44	SG	924101
Chlordane	ND		0.5		1		11/26/01 23:44	SG	924101
delta-BHC	ND		0.05		1		11/26/01 23:44	SG	924101
Dieldrin	ND		0.1		1		11/26/01 23:44	SG	924101
Endosulfan I	ND		0.05		1		11/26/01 23:44	SG	924101
Endosulfan II	ND		0.1		1		11/26/01 23:44	SG	924101
Endosulfan sulfate	ND		0.1		1		11/26/01 23:44	SG	924101
Endrin	ND		0.1		1		11/26/01 23:44	SG	924101
Endrin aldehyde	ND		0.1		1		11/26/01 23:44	SG	924101
Endrin ketone	ND		0.1		1		11/26/01 23:44	SG	924101
gamma-BHC	ND		0.05		1		11/26/01 23:44	SG	924101
gamma-Chlordane	ND		0.05		1		11/26/01 23:44	SG	924101
Heptachlor	ND		0.05		1		11/26/01 23:44	SG	924101
Heptachlor epoxide	ND		0.05		1		11/26/01 23:44	SG	924101
Methoxychlor	ND		0.5		1		11/26/01 23:44	SG	924101
Toxaphene	ND		1		1		11/26/01 23:44	SG	924101
Surr: Decachlorobiphenyl	89.9	%	40-150		1		11/26/01 23:44	SG	924101
Surr: Tetrachloro-m-xylene	55.7	%	39-106		1		11/26/01 23:44	SG	924101

Prep Method	Prep Date	Prep Initials
SW3510B	11/17/2001 8:16	KL

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Fanny 112001 **Collected:** 11/13/01 3:00:00 **SPL Sample ID:** 01110644-07

Site: **USAID Groundwater 21365**

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		11/28/01 12:59	R_T	932135

Prep Method	Prep Date	Prep Initials
SW7470A	11/28/2001 8:45	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		11/27/01 5:49	NS	927030
Arsenic	0.0266	0.005		1		11/27/01 5:49	NS	927030
Lead	ND	0.005		1		11/27/01 5:49	NS	927030
Selenium	ND	0.005		1		11/27/01 5:49	NS	927030
Cadmium	ND	0.005		1		11/25/01 15:36	EG	925321
Chromium	ND	0.01		1		11/25/01 15:36	EG	925321
Nickel	ND	0.02		1		11/25/01 15:36	EG	925321
Silver	ND	0.01		1		11/25/01 15:36	EG	925321
Zinc	ND	0.02		1		11/25/01 15:36	EG	925321

Prep Method	Prep Date	Prep Initials
SW3005	11/16/2001 14:30	MME

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Guadalupe Lopez 112001 **Collected:** 11/13/01 12:00:0 **SPL Sample ID:** 01110644-06

Site: **USAID Groundwater 21365**

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		11/28/01 12:59	R_T	932134

Prep Method	Prep Date	Prep Initials
SW7470A	11/28/2001 8:45	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		11/27/01 5:43	NS	927028
Arsenic	0.0257	0.005		1		11/27/01 5:43	NS	927028
Lead	ND	0.005		1		11/27/01 5:43	NS	927028
Selenium	ND	0.005		1		11/27/01 5:43	NS	927028
Cadmium	ND	0.005		1		11/25/01 15:30	EG	925320
Chromium	ND	0.01		1		11/25/01 15:30	EG	925320
Nickel	ND	0.02		1		11/25/01 15:30	EG	925320
Silver	ND	0.01		1		11/25/01 15:30	EG	925320
Zinc	ND	0.02		1		11/25/01 15:30	EG	925320

Prep Method	Prep Date	Prep Initials
SW3005	11/16/2001 14:30	MME

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

JORDANLAB
Laboratorio de Analisis Industrial
Agua Potable, Residual e Industrial Ambientes de Trabajo, Alimentos

6 Ave. 5-6 Calle S.O. San Pedro Sula, Cortés
R. T. N. X4RRMA-U TELFAX: 557-5802, Email: jordanlab@hn2.com

Duplicado

BROWN AND CALDWELL

Solicitado por: Ing. Barbara Goodrich
Fecha de Ingreso: 13/11/01
Muestra # 1238, Guadalupe Lopez 112001
Muestra # 1239, Fanny 112001
Lugar Toma de Muestras: Villanueva

	Norma Nacional			Fecha	13/11/2001	13/11/2001
				Hora	12:00	15:00
				Muestra	Guadalupe	Fanny
Parametros	Unidades	Recomen.	Max. Adm.	Metodo &	1238	1239
pH		6.5 a 8.5		4500-H-B	7.00	6.88
Acidez Total	mg/l			2310-B	85	49
Conductividad	us/cm	400		25100-B	890	859
Alcalinidad Total	mg/l CaCO3			2320-B	375	372
Dureza Total	mg/l CaCO3	400		2340-C	196	196
Bicarbonato (HCO3)	mg/l			2320-B	375	372
Calcio	mg/l CaCO3	100		3500-Ca-D	55	56
Magnesio	mg/l CaCO3	30	50	3500-Mg E	14	13
Hierro Total	mg/l		0.3	3500-Fe D	<0.03	<0.03
Hierro Filtrado	mg/l			3500-Fe D	<0.03	<0.03
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	<0.03	<0.03
Manganeso Filtrado	mg/l			3500-Mn C	<0.03	<0.03
Cloruros	mg/l	25	250	4500-Cl-B	69	59
Sulfatos	mg/l	25	250	4500-SO4	45	44
Nitritos	mg/l		1	4500-NO2-B	<0.01	<0.01
Nitratos	mg/l	25	50	4500-NO3-B	2.00	1.81
Sodio (Na)*	mg/l	25	200	AA	130.05	126.8
Potasio (K)*	mg/l		10	AA	10.28	8.26
ANALISIS MICROBIOLOGICOS						
Coliformes Totales		UFC/100ml	0	9222-B	0	0
Coliformes Fecales		UFC/100ml	0	9222-D	0	0

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL

LIC. LILIA J. DE RIVERA
JORDANLAB

San Pedro Sula, 21 de Noviembre del 2,001

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Marvel Goello 112001 **Collected:** 11/12/01 1:32:00 **SPL Sample ID:** 01110644-03

Site: **USAID Groundwater 21365**

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		11/28/01 12:59	R_T	932131

Prep Method	Prep Date	Prep Initials
SW7470A	11/28/2001 8:45	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		11/27/01 5:09	NS	927017
Arsenic	ND	0.005		1		11/27/01 5:09	NS	927017
Lead	ND	0.005		1		11/27/01 5:09	NS	927017
Selenium	ND	0.005		1		11/27/01 5:09	NS	927017
Cadmium	ND	0.005		1		11/25/01 14:39	EG	925315
Chromium	ND	0.01		1		11/25/01 14:39	EG	925315
Nickel	ND	0.02		1		11/25/01 14:39	EG	925315
Silver	ND	0.01		1		11/25/01 14:39	EG	925315
Zinc	ND	0.02		1		11/25/01 14:39	EG	925315

Prep Method	Prep Date	Prep Initials
SW3005	11/16/2001 14:30	MME

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Pintala I 112001 **Collected:** 11/12/01 11:30:0 **SPL Sample ID:** 01110644-01

Site: **USAID Groundwater 21365**

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**	**Units: mg/L**		
Mercury	ND	0.0002	1		11/28/01 12:59	R_T	932125

Prep Method	Prep Date	Prep Initials
SW7470A	11/28/2001 8:45	R_T

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**	**Units: mg/L**		
Antimony	ND	0.005	1		11/27/01 4:31	NS	927009
Arsenic	ND	0.005	1		11/27/01 4:31	NS	927009
Lead	ND	0.005	1		11/27/01 4:31	NS	927009
Selenium	ND	0.005	1		11/27/01 4:31	NS	927009
Cadmium	ND	0.005	1		11/25/01 14:27	EG	925313
Chromium	ND	0.01	1		11/25/01 14:27	EG	925313
Nickel	ND	0.02	1		11/25/01 14:27	EG	925313
Silver	ND	0.01	1		11/25/01 14:27	EG	925313
Zinc	ND	0.02	1		11/25/01 14:27	EG	925313

Prep Method	Prep Date	Prep Initials
SW3005	11/16/2001 14:30	MME

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Victoria 112001 **Collected:** 11/12/01 1:12:00 **SPL Sample ID:** 01110644-02

Site: **USAID Groundwater 21365**

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		11/28/01 12:59	R_T	932128

Prep Method	Prep Date	Prep Initials
SW7470A	11/28/2001 8:45	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		11/27/01 5:02	NS	927015
Arsenic	ND	0.005		1		11/27/01 5:02	NS	927015
Lead	ND	0.005		1		11/27/01 5:02	NS	927015
Selenium	ND	0.005		1		11/27/01 5:02	NS	927015
Cadmium	ND	0.005		1		11/25/01 14:33	EG	925314
Chromium	ND	0.01		1		11/25/01 14:33	EG	925314
Nickel	ND	0.02		1		11/25/01 14:33	EG	925314
Silver	ND	0.01		1		11/25/01 14:33	EG	925314
Zinc	0.02	0.02		1		11/25/01 14:33	EG	925314

Prep Method	Prep Date	Prep Initials
SW3005	11/16/2001 14:30	MME

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

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8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Villalinda 112001 **Collected:** 11/12/01 3:00:00 **SPL Sample ID:** 01110644-05

Site: USAID Groundwater 21365

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		11/28/01 12:59	R_T	932133

Prep Method	Prep Date	Prep Initials
SW7470A	11/28/2001 8:45	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		11/27/01 5:37	NS	927025
Arsenic	0.00694	0.005		1		11/27/01 12:43	NS	927071
Lead	ND	0.005		1		11/27/01 5:37	NS	927025
Selenium	ND	0.005		1		11/27/01 5:37	NS	927025
Cadmium	ND	0.005		1		11/25/01 15:24	EG	925319
Chromium	ND	0.01		1		11/25/01 15:24	EG	925319
Nickel	ND	0.02		1		11/25/01 15:24	EG	925319
Silver	ND	0.01		1		11/25/01 15:24	EG	925319
Zinc	ND	0.02		1		11/25/01 15:24	EG	925319

Prep Method	Prep Date	Prep Initials
SW3005	11/16/2001 14:30	MME

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

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8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Villa Sol 112001 **Collected:** 11/14/01 2:30:00 **SPL Sample ID:** 01110913-09

Site: La Lima-Villanueva

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		12/05/01 11:10	R_T	937623

Prep Method	Prep Date	Prep Initials
SW7470A	12/05/2001 9:00	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		12/06/01 3:48	NS	938738
Arsenic	ND	0.005		1		12/06/01 3:48	NS	938738
Lead	ND	0.005		1		12/06/01 3:48	NS	938738
Selenium	ND	0.005		1		12/06/01 3:48	NS	938738
Cadmium	ND	0.005		1		12/07/01 22:44	EG	940240
Chromium	ND	0.01		1		12/07/01 22:44	EG	940240
Nickel	ND	0.02		1		12/07/01 22:44	EG	940240
Silver	ND	0.01		1		12/07/01 22:44	EG	940240
Zinc	ND	0.02		1		12/07/01 22:44	EG	940240

Prep Method	Prep Date	Prep Initials
SW3005A	11/25/2001 11:00	MW

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
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BROWN AND CALDWELL

Solicitado por: Ing. Barbara Goodrich
Fecha de Ingreso: 14/11/01
Lugar Toma de Muestras: Villanueva

				Fecha	14/11/2001
				Hora	15:20
	Norma Nacional			Muestra	Villa Sol-112001
Parametros	**Unidades**	**Recomen.**	**Max. Adm.**	**Metodo &**	**1240**
Acidez Total	mg/l			2310-B	52
Conductividad	us/cm	400		25100-B	915
Alcalinidad Total	mg/l CaCO3			2320-B	357
Dureza Total	mg/l CaCO3	400		2340-C	376
Bicarbonato (HCO3)	mg/l			2320-B	357
Calcio	mg/l CaCO3	100		3500-Ca-D	75
Magnesio	mg/l CaCO3	30	50	3500-Mg E	45
Hierro Total	mg/l		0.3	3500-Fe D	<0.03
Hierro Filtrado	mg/l			3500-Fe D	<0.03
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	<0.03
Manganeso Filtrado	mg/l			3500-Mn C	<0.03
Cloruros	mg/l	25	250	4500-Cl-B	39
Sulfatos	mg/l	25	250	4500-SO4	61.2
Nitritos	mg/l		1	4500-NO2-B	<0.01
Nitratos	mg/l	25	50	4500-NO3-B	22.2
Sodio (Na)*	mg/l	25	200	AA	34.80
Potasio (K)*	mg/l		10	AA	4.98
ANALISIS MICROBIOLOGICOS					
Coliformes Totales		UFC/100ml	0	9222-B	40
Coliformes Fecales		UFC/100ml	0	9222-D	4

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL

LIC. OLIA J. DE RIVERA
JORDANLAB

San Pedro Sula, 21 de Noviembre del 2,001

APPENDIX C

Groundwater Flow Model

GROUNDWATER FLOW MODEL

Villanueva, Honduras

June 2002

1.0 INTRODUCTION

The City of Villanueva (Villanueva) is located approximately 39 kilometers south of the City of San Pedro Sula. The population of Villanueva is estimated to be approximately 80,000 inhabitants, with an additional 15,000 transient inhabitants that work in nearby industrial parks. Villanueva relies almost entirely on groundwater for its water supply, which is pumped from approximately 20 wells within and around Villanueva. Three of the wells are located within a sugar cane plantation area south of Villanueva and are the major source of water for Villanueva.

A steady-state groundwater flow model was constructed for Villanueva as a potential interpretive tool to evaluate the groundwater resources available for the community. The preliminary groundwater flow model was constructed consistent with our understanding of existing hydrogeologic conditions. The model was intended to be used to evaluate the potential groundwater resources of the Villanueva Valley. However, because of the complexity of the geology and hydrogeology in the valley and the limited data available for the development of the conceptual model, the use of this groundwater model should be limited to developing a general understanding of potential groundwater resources in the valley. As additional geologic and hydrogeologic data are collected, the site conceptual model and groundwater flow model can be updated, thereby increasing the effectiveness of the groundwater flow model as a tool to manage the valley's groundwater resources.

The steady-state groundwater flow-model was converted to run in a transient mode so that predictive simulations of increased groundwater pumping could be performed. Two separate simulations were performed, one with increased groundwater production north of Villanueva, and one with increased groundwater production south of Villanueva.

2.0 OBJECTIVES

The primary purpose and goal of this task was to develop a groundwater flow model to function as a potential interpretive tool to evaluate possible groundwater resources for the community of Villanueva.

2.1 Applicability

The objective of this task is to develop a numeric groundwater flow model that supports the development of a water resources management plan for Villanueva. Villanueva has experienced rapid growth in recent years. The recent expansion of industrial parks have resulted in increased residential water supply demand, as well as growth in population. The intent of the model is for use in the evaluation of potential groundwater resources available to support this population growth and increased water use due to industry.

The information collected to date, the current conceptual hydrogeologic model, and the groundwater flow model should serve as the basis for an initial understanding of the site. As additional geologic and hydrogeologic data are collected, the site conceptual model and understanding of groundwater flow can be refined, thereby increasing the effectiveness of the groundwater flow model if used as a tool to sustainably manage the community's groundwater resources.

3.0 MODEL APPROACH

The approach used in modeling the groundwater flow system of the Villanueva area was to incorporate newly acquired and previously determined aquifer data into a conceptual groundwater flow model that encompasses the entire Villanueva Valley. The conceptual model was then used as the basis for the development of a numerical groundwater flow model. This approach attempts to account for all of the elements of the groundwater budget for the Villanueva Valley, which provides a tool for assessing the potential impacts of current and projected groundwater extraction on the groundwater resource.

4.0 MODEL ASSUMPTIONS

Several assumptions were necessary in the development of the Villanueva groundwater model because of the limited data available on the hydrogeologic system of the valley. The data that are available are primarily from recently completed borehole logs and aquifer testing, and are limited to a small portion of the modeled area where recent groundwater development has occurred.

Following is a summary of the assumptions used in the development of the Villanueva groundwater model:

- Groundwater flow directions throughout the modeled area are generally to the south, toward the Ulua River.
- Areal recharge occurs over the entire surface of the modeled area at a uniform rate.
- Mountain front recharge to the modeled area is proportional to the areas of the watersheds in the surrounding highlands.
- The Ulua River fully penetrates the modeled aquifer system and controls the hydraulic head at the southern model boundary.

As stated above, groundwater flow directions in the conceptual model are assumed to be generally to the south, with all of the groundwater in the Villanueva Valley originating as underflow from the surrounding limestone highlands and from areal recharge. However, surface drainages in the northeastern portion of the modeled area flow to the east through the Sirena Hills. If groundwater flow directions are similar to surface water flow directions in the northeastern portion of the Villanueva Valley, then the groundwater budget for the Villanueva area would be reduced by the volume of water exiting the valley to the east.

5.0 CONCEPTUAL MODEL

A conceptual groundwater flow model is constructed for the purpose of simplifying the groundwater flow system and organizing the data so that the system can be numerically modeled

(Anderson and Woessner, 1992). The following sections describe the components of the conceptual groundwater model for Villanueva.

5.1 Hydrogeologic Boundaries

The modeled area is bounded on the eastern, northeastern and western margins by limestone highlands, where a portion of the precipitation infiltrates into the bedrock and then migrates toward modeled area. The groundwater originating in the surrounding highlands enters the alluvial basin, providing a substantial portion of the groundwater budget of the modeled area.

The northern boundary of the modeled area is conceptualized as a groundwater divide. Groundwater to the north of the divide flows northward away from the modeled area, and groundwater to the south of the divide flows southward into the modeled area.

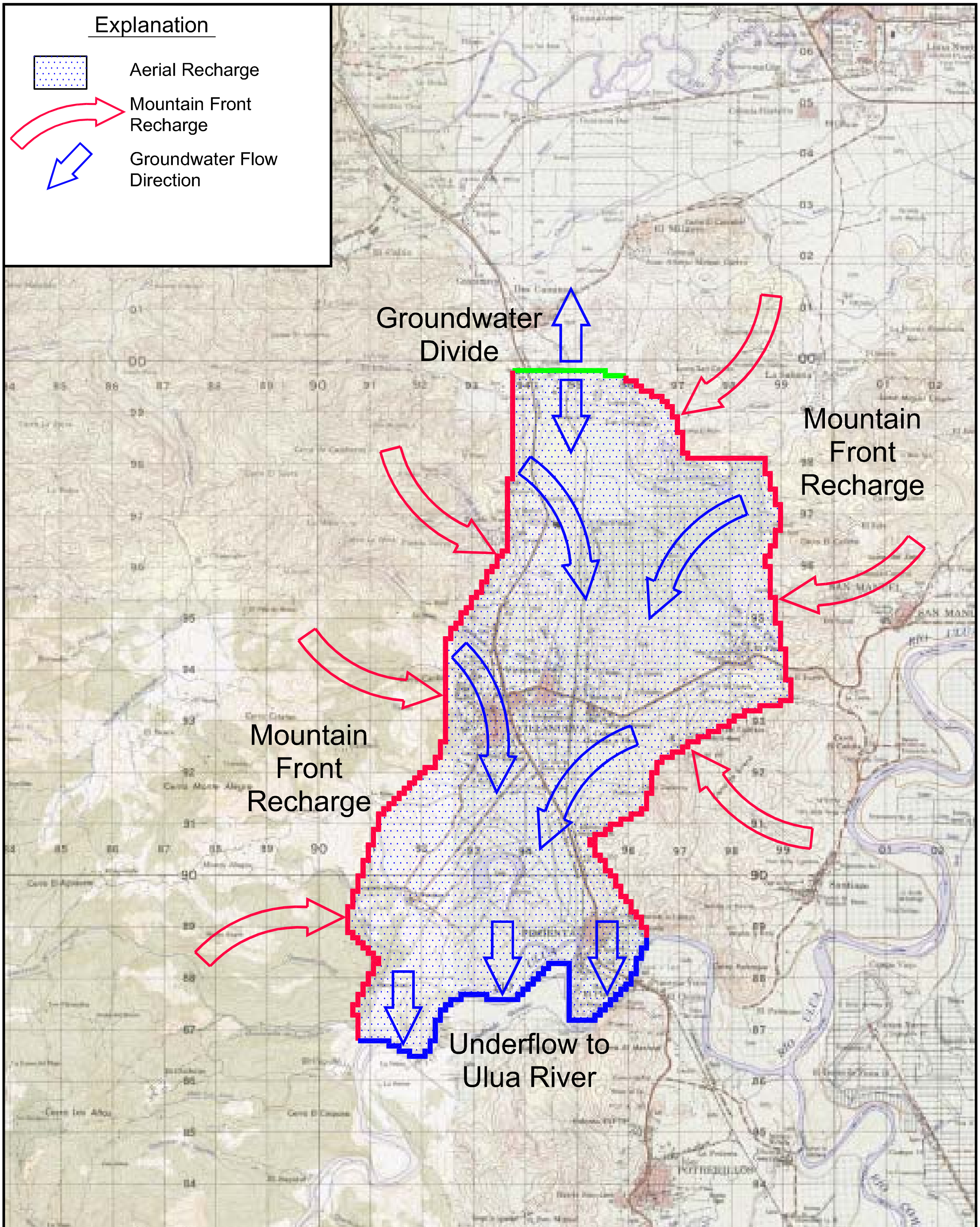
The southern margin of the modeled area is bounded by the Ulua River, which is assumed to fully penetrate the vertical extent of the modeled aquifer system. As such, the Ulua River forms a constant head boundary for the aquifer system. Figure G1 presents the area covered by the Villanueva groundwater model and the conceptual groundwater flow.

5.2 Hydraulic Properties

In the conceptual model, the hydraulic properties of the aquifer system are simplified into three main groups. Most important for groundwater production in the Villanueva Valley are the highly transmissive sediments of the Ulua River, which extend northward from the present position of the Ulua River to near the southern edge of the City of Villanueva. The second most important group of sediments for groundwater production in Villanueva is the ancient river channel deposits that extend northward from the Ulua River sediments roughly along the alignment of the railroad through Villanueva. The channel sediments are less transmissive than the Ulua River sediments and are of limited extent in an east-west direction. The third group comprises the valley margin deposits, which lap onto the edges of the surrounding highlands. The valley margin sediments are the least transmissive deposits in the modeled area, and are not considered to be a significant groundwater producing unit.

5.3 Conceptual Water Budget

Groundwater enters aquifer system of the modeled area as mountain front recharge from the surrounding highlands along the eastern, northeastern and western boundaries of the modeled area. The portions of the surrounding highlands that are within the watershed of the Villanueva Valley are believed to contribute groundwater to the aquifer system in the modeled area. Of the total precipitation that falls on the contributing watersheds (2 to 3 meters, annually), approximately four percent is assumed to enter the modeled area as mountain front recharge. It is assumed that the mountain's watershed areas receive more precipitation than the valley floor. The average annual precipitation (2.5 meters) was used to calculate the mountain front recharge portion of the conceptual water budget. The total estimated contribution to the Villanueva Valley aquifer system from mountainfront recharge is 6.0 m^3/year.



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Carson City, Nevada

SCALE:
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SCALE IN METERS

Figure C-1

Villanueva Model Area and Conceptual Groundwater Flow

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Precipitation falling directly on the modeled area is also assumed to contribute water to the aquifer system. Of the total precipitation that falls on the surface of the modeled area (estimated to be 2 meters annually), approximately two percent is assumed to infiltrate to the aquifer system. The total estimated contribution to the Villanueva Valley aquifer system from areal recharge is 2,495,200 m^3/year.

Groundwater leaves the modeled area through groundwater production wells and as flow from the aquifer system to the Ulua River. The combined average production of the primary municipal and non-municipal water production wells in the Villanueva Valley is estimated to be 4,828,267 m^3/year. Discharge to the Ulua River was estimated based on a 5,835-meter straight-line section of the Ulua River, a 247-meter depth, an estimated hydraulic conductivity of 15 meters per day, and a hydraulic gradient of 0.0005. Discharge to the Ulua River using this method is estimated to be approximately 3,945,436 m^3/year. Table C-1 presents the conceptual groundwater budget for the Villanueva groundwater model.

Table C-1. Conceptual Groundwater Budget

IN	M^3 per year	gallons per minute
Mountain Front Recharge	6,038,195	3,035
Areal Recharge	2,495,200	1,254
Total	8,533,395	4,289
OUT		
Production Wells	4,828,267	2,427
Discharge to Ulua River	3,945,436	1,983
Total	8,773,703	4,410

Based on these estimates, there is a yearly deficit of 240,308 m^3 or approximately 121 gpm, indicating that groundwater supplies are being removed from storage.

6.0 MODEL DESIGN

MODFLOW™, a modular, three-dimensional, finite difference groundwater flow model developed by McDonald and Harbaugh (1988) was used to simulate hydraulic heads for the Villanueva model. Groundwater Vistas (Environmental Simulations, Inc., 1997) was used as a pre- and post-processor for the MODFLOWTM simulations.

6.1 Model Domain

The finite difference grid designed for the Villanueva model is presented in Figure C-2. The grid cells are a uniform 100 meters, with 140 rows and 100 columns. The area covered by the grid is thus 14,000 meters by 10,000 meters, or 140 square kilometers. However, of the total area covered by the grid, only 62.38 square kilometers are active (Figure C-2). The y-direction of the grid is oriented north-south, coincident with the primary direction of groundwater flow.

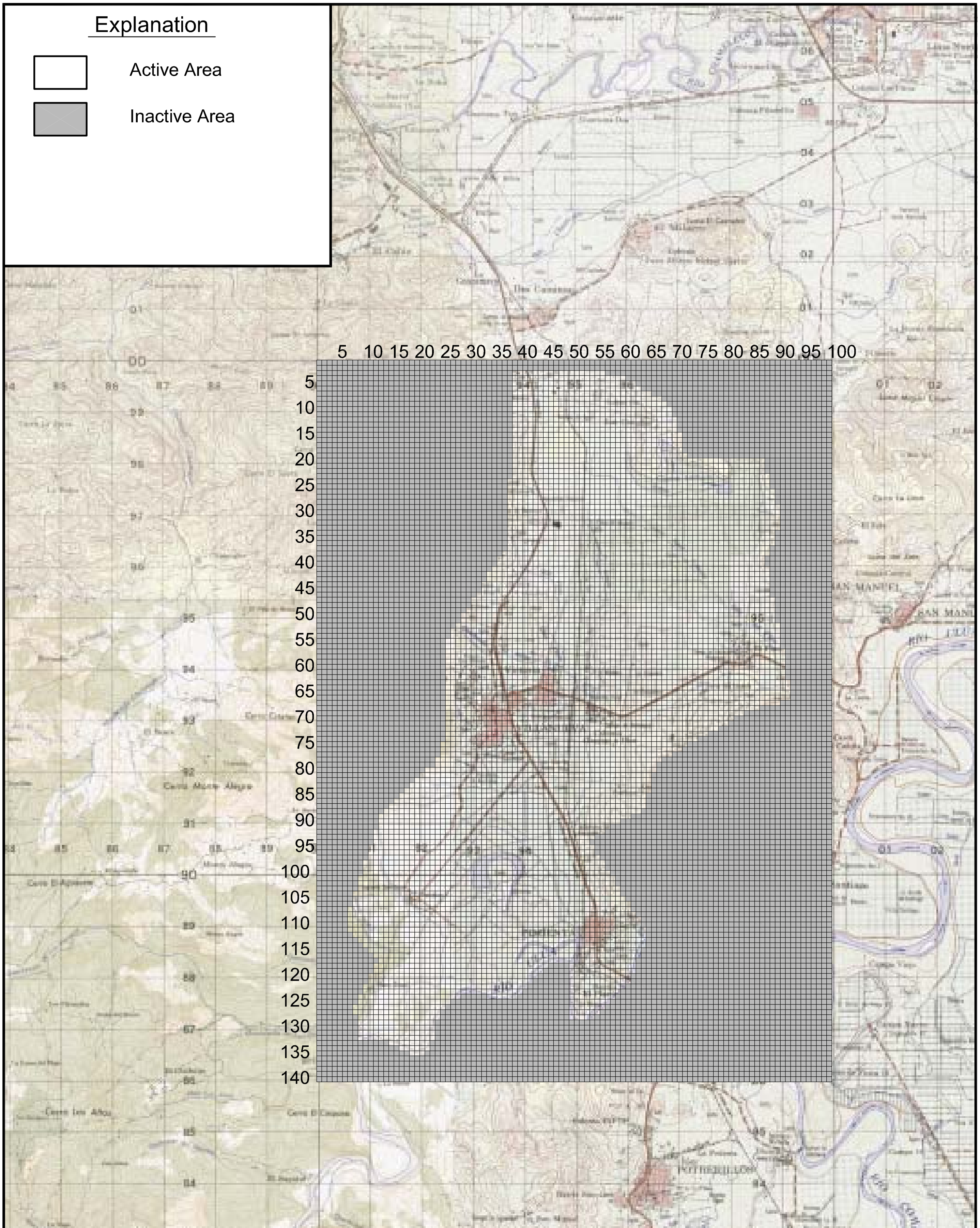

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Figure C-2

Villanueva Model Grid

The model was vertically discretized into two layers, each with identical horizontal extents. The upper layer of the model extends vertically from the ground surface (chosen as 130 meters amsl) to mean sea level, and the lower layer extends from sea level to 210 meters below mean sea level.

Layer 1 represents the uppermost, unconfined portion of the alluvial aquifer system underlying Villanueva. Layer 2 represents the lower, confined portion of the alluvial aquifer system. The most prolific groundwater production wells in the Villanueva area, including the wells located in the sugar cane plantation area to the south of Villanueva, are completed either in Layer 2 or in both Layers 1 and 2. Many of the smaller production wells are located in only Layer 1.

6.2 Hydraulic Parameters

Hydraulic parameters for the model are estimated from the results of constant rate aquifer testing in wells BC VI-2 and BC VI-5, which were monitored in wells BC VI-3 and BC VI-4, respectively. The BC VI-5 test provided hydraulic data for the Ulua River sediments, and the BC VI-2 test provided hydraulic data for the channel deposits.

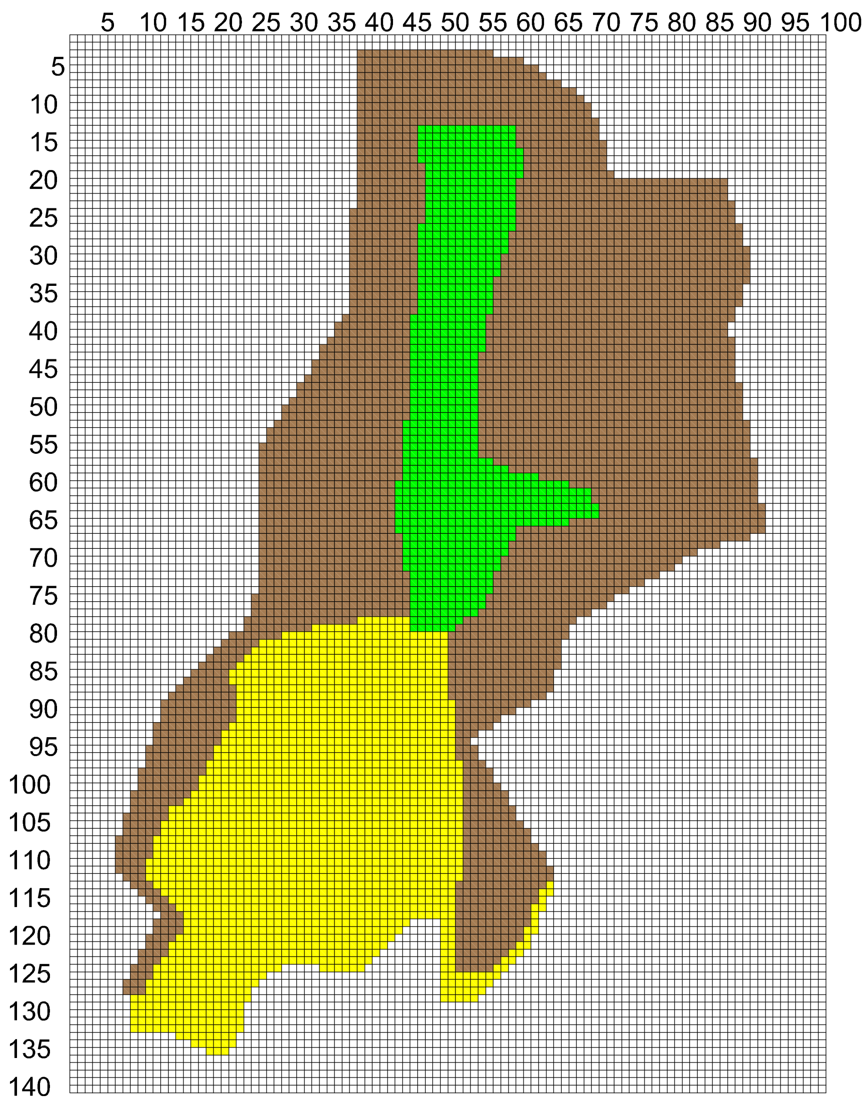
Hydraulic conductivity values were input to the model as zones (Figure C-3). A hydraulic conductivity of approximately 15 meters per day was calculated for the Ulua River deposits (hydraulic conductivity Zone 1) from the results of the constant rate aquifer test conducted in well BC VI-5. A hydraulic conductivity of approximately 5 meters per day was calculated for the channel deposits (hydraulic conductivity Zone 2) from the results of the constant rate aquifer test conducted in well BC VI-2. The hydraulic properties of the valley margin deposits were estimated to be approximately 1 meter per day by comparing the production rates of wells completed in the valley margin deposits to the production rates of wells completed in the channel and Ulua River deposits. Vertical hydraulic conductivity values were assumed to be one tenth of the horizontal hydraulic conductivity for each of the three hydrogeologic units (Zones 1 through 3) that comprise the aquifer system. Hydraulic parameters input to the Villanueva groundwater model are presented in Table C-2.

Table C-2. Hydrogeologic Parameters

Hydrogeologic Parameter	Estimated Value
Mountain precipitation	2.5 meters per year
Mountain front recharge	6,038,195 m^3 per year
Model area precipitation	2.0 meters per year
Areal recharge	0.00011 meters per year
Solver	PCG2
Convergence criteria	0.001 meters
Layer 1	
Horizontal hydraulic conductivity	1 to 15 meters per day
Vertical hydraulic conductivity	0.1 meters per day
Thickness	130 meters
Specific yield	0.30 meters
Layer 2	
Horizontal hydraulic conductivity	1 to 15 meters per day
Vertical hydraulic conductivity	0.5 to 1.5 meters per day
Thickness	210 meters
Storativity	0.00075 meters

Explanation

- Hydraulic Conductivity = 15 m/day
- Hydraulic Conductivity = 5 m/day
- Hydraulic Conductivity = 1 m/day



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Carson City, Nevada

Figure C-3

Villanueva Model Layer 1 and Layer 2 Hydraulic Conductivity Zones

6.3 Sources and Sinks

Sources of groundwater to the model area include mountain front and areal recharge. Mountain front recharge was estimated by measuring the areas of the watersheds that contribute to the modeled area (Figure C-4), and then assuming that approximately four percent of the precipitation falling on the watersheds infiltrates into the mountain block and then migrates to the valley. The mountain front recharge is assumed to enter the valley alluvium where it recharges the aquifer system. Mountain front recharge to the model was divided evenly between Layer 1 and Layer 2.

Areal recharge was distributed evenly over the surface of the modeled area. The areal recharge rate was assumed to be equal to approximately two percent of the average annual precipitation.

Groundwater sinks in the Villanueva model include groundwater production wells and flow to the Ulua River. A total of 20 groundwater production wells are included in the model. Pumping rates for the wells were averaged over time by dividing the documented production rate by the reported number of hours each well pumps per day to provide an average daily pumping rate. The wells that are included in the model, along with the estimated daily average pumping rates, are presented in Table C-3.

Table C-3. Pumping Wells

Well Name	Average Pumping Rate, gpm
La Victoria	120
Colonia Buena Vista	30
Pintala I	32
Independencia II	15
Julio Solis	50
Manuel Coello	400
Villa Linda Norte	40
Caneras No.3	200
Caneras No.2	600
Tres Rosas	25
Colonia Villasol	14
Vivero Municipal	30
ZIP Villanueva Grupo J #2	70
El Rastro Municipal	70
Gracias a Dios	55
Colonia Suyapa	30
Orquidea III No.2	20
Guadalupe Lopez	150
Independencia I	25
Pintala II	450
Total	2,426

Note: Includes both municipal and non-municipal wells.

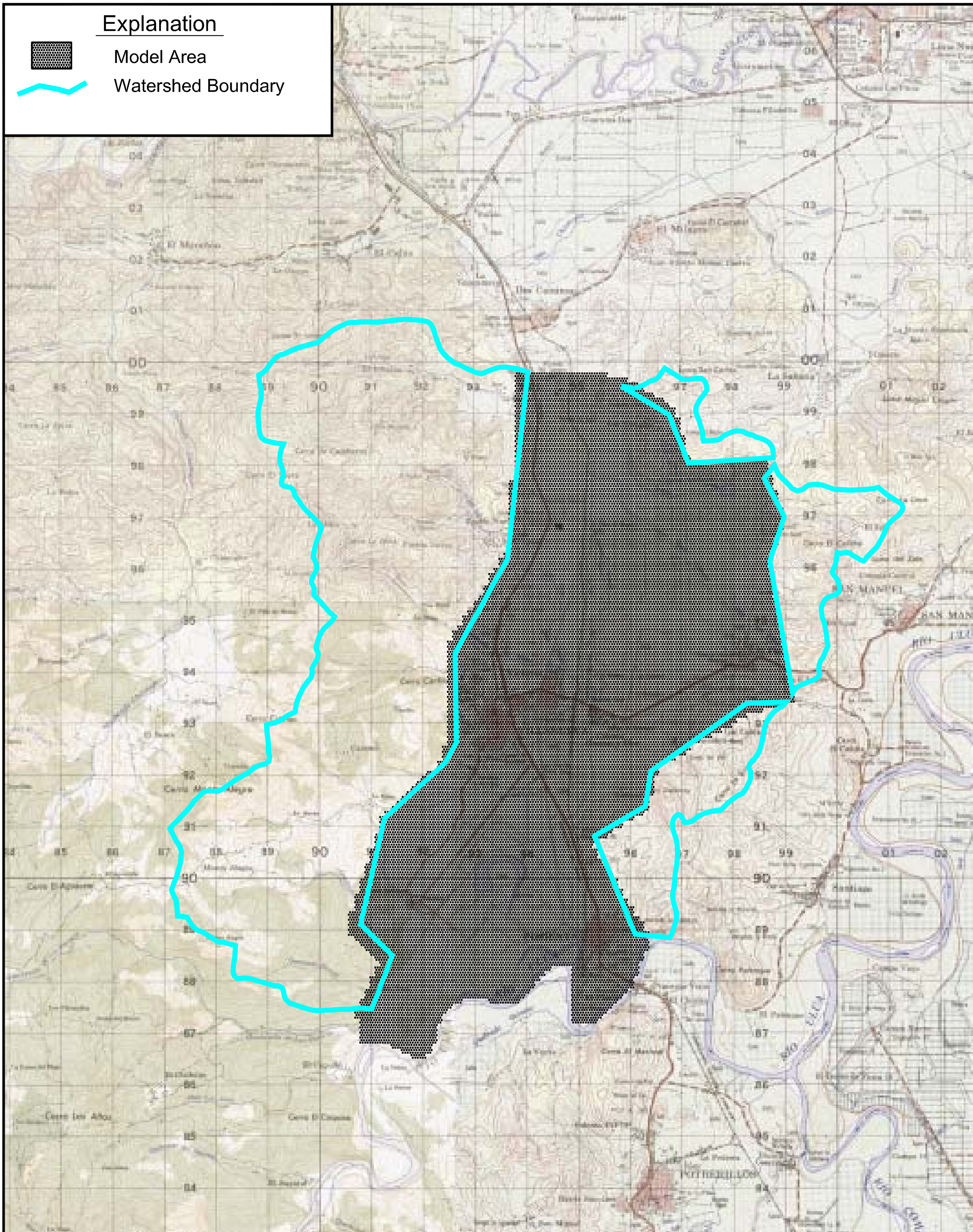

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Figure C-4

Villanueva Model Contributing Watersheds

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6.4 Boundary Conditions

Boundary conditions for the Villanueva model are comprised of constant flux, constant head, and no-flow boundaries. Figure C-5 presents the locations of the model boundary conditions.

Constant flux boundaries are used along the western, eastern, and northeastern margins of the Villanueva Valley basin. The total contribution from each of the watersheds discussed in Section 5.3 was subdivided into shorter reaches for watershed regions 1 and 2 to better distribute mountain front recharge to the groundwater model. The percentage of the total recharge from the watershed regions was apportioned to each of the reaches by visual estimate. The locations of the individual mountain front recharge reaches are shown on Figure C-5.

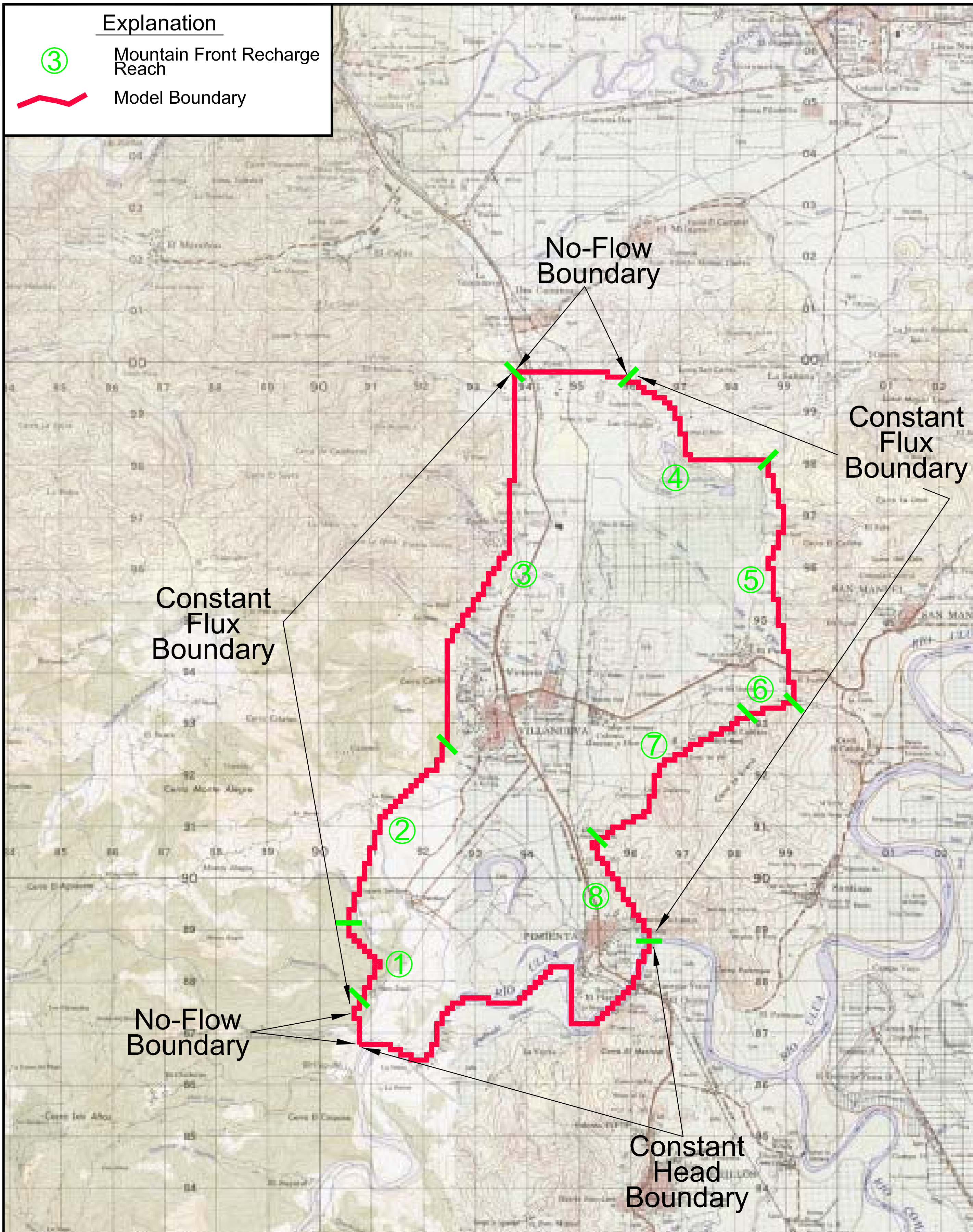
A constant head boundary is used to bound the southern portion of the Villanueva groundwater model at the Ulua River (Figure C-5). Accurate measurements of the river surface were not available. Therefore, the elevation of the constant head boundary was estimated to be 37 meters amsl, which is three meters below the nearest ground surface contour to the river (40 meters).

A no-flow boundary was used to represent a suspected groundwater divide in the northern portion of the Villanueva Valley, approximately one kilometer south of the town of Dos Caminos. Another segment of no-flow boundary is incorporated in the model between the Ulua River and the southern edge of the Reach 1 recharge boundary (Figure C-5).

7.0 CALIBRATION AND SENSITIVITY ANALYSIS

The steady-state Villanueva groundwater model was calibrated by comparing model-predicted heads to measured groundwater elevations in four wells. Production from the 20 wells described in Section 5.3 was included in the calibration simulations. The number of calibration targets available for calibration was limited because of obvious or suspected errors in the reported ground surface elevations or depth to water in most of the wells in Villanueva. The four wells chosen as calibration targets are BC VI-2, BC VI-4, Llanos de Canada, and Caneras 3, which are all located in or south of Villanueva (Figure C-6) and are completed in Layer 2. No calibration targets were available for the northern or northeastern portions of the model area.

Calibration was achieved by a slight adjustment in the areal recharge flux to the model. For the limited amount of data available for the Villanueva aquifer system, the model calibrated fairly well. Of the four calibration targets, the predicted groundwater elevation was lower than the measured groundwater elevation by 0.25 to 0.36 meters. At the fourth calibration target, the predicted groundwater elevation was higher than the measured groundwater elevation by 0.56 meters. Calibration residuals, which are measured groundwater elevations minus model-predicted groundwater elevations, and Layer 2 modeled groundwater elevation contours are presented in Figure C-6.



DATE: Jan. 2002	PROJECT NUMBER: 21143	SCALE: 0 1000 2000 SCALE IN METERS		Figure C-5

BROWN AND CALDWELL
Carson City, Nevada

Figure C-5

Villanueva Model Boundary Conditions and Mountain Front Recharge Reaches

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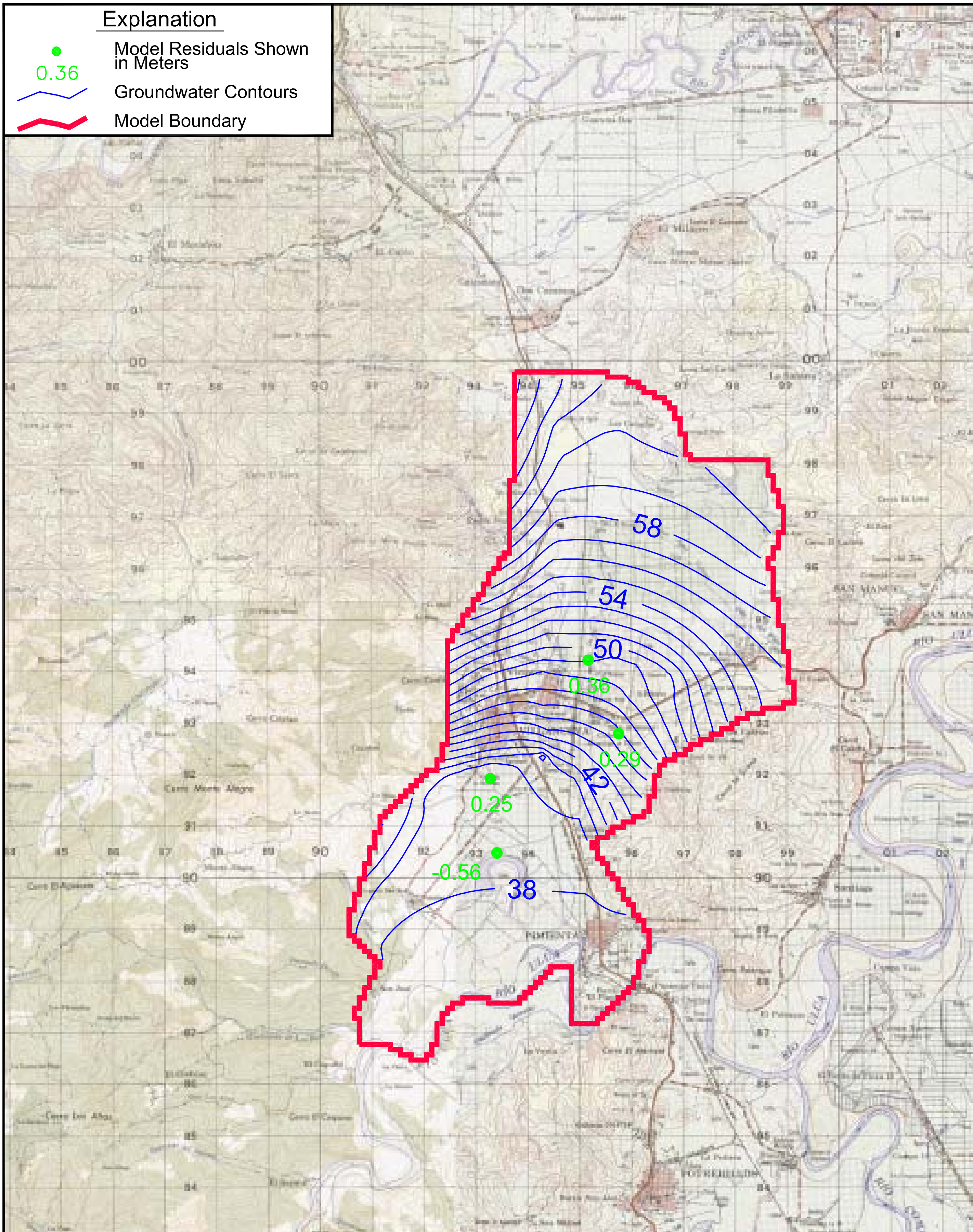

DATE: Jan. 2002

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BROWN AND CALDWELL
Carson City, Nevada

Figure C-6

Villanueva Model Calibrated Layer 2 Groundwater Elevation Contours and Calibration Residuals

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A sensitivity analysis was performed to evaluate the sensitivity of the model output to uncertainties inherent in the input data. The first step in this process was to establish reasonable ranges within which to vary the input parameters. Parameter values were increased and decreased to represent reasonable upper and lower limits. The sensitivity analysis was conducted by varying one input parameter at a time and comparing the predicted steady-state match with that of the calibrated base case simulation.

The results of the sensitivity analysis indicate that the model is most sensitive to variations in hydraulic conductivity in Zone 2 (Figure C-3), the mountain front recharge in Reach 3 (Figure C-5), and areal recharge. The residuals did not increase substantially with changes in the hydraulic conductivity in Zone 2 until the hydraulic conductivity value was increased by a factor of four or decreased by a factor of 0.1. The model residuals increased substantially in response to changes of a factor of four or greater in the Reach 3 boundary. Model residuals increased substantially with an increase in areal recharge of greater than a factor of four, and were relatively unchanged with decreasing values of areal recharge.

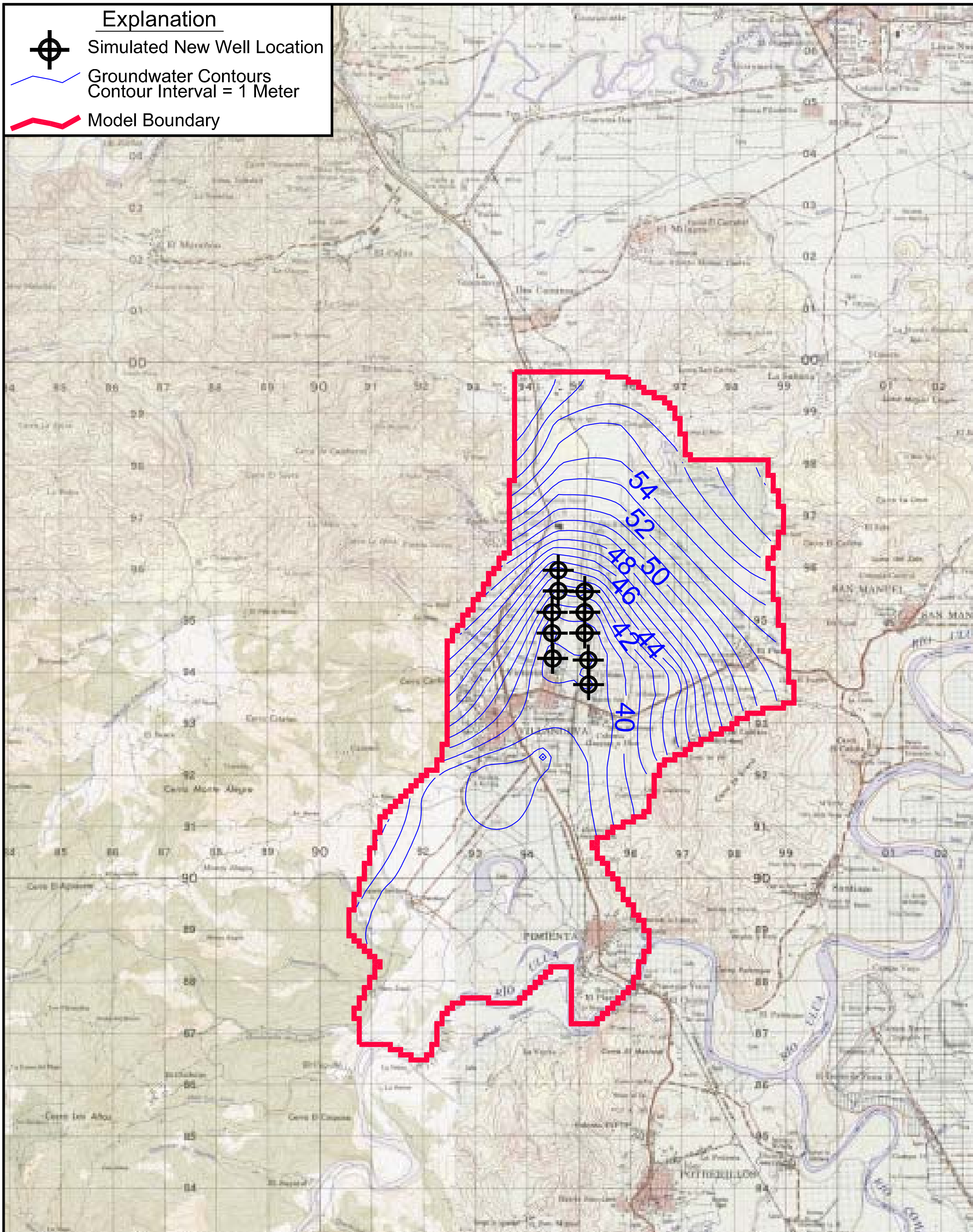
8.0 PREDICTIVE SIMULATIONS

Two predictive model simulations were performed to evaluate the potential effects of increased groundwater production on the Villanueva Valley aquifer system. Pumping rates were incrementally increased over the duration of the simulations to a maximum groundwater production rate of 5,887 gpm. Each of the simulations was run for a predictive period of 25 years. The first of these simulations uses hypothetical production wells located to the north of Villanueva, near the area of current population growth. The second of these simulations uses hypothetical production wells located to the south of Villanueva, near the existing high capacity cane field production wells. Because of a lack of appropriate data, the transient model was not calibrated.

To accomplish the predictive simulations, the groundwater model was first converted to run in transient mode, with the calibrated steady-state water levels used for initial water level conditions. Transient model simulations are used to analyze time-dependent problems, and produce a set of hydraulic heads for each pre-determined time step (Anderson and Woessner, 1992). A steady state model simulation produces a set of hydraulic heads that are in equilibrium with stresses on the model, whereas a transient simulation produces a set of hydraulic heads that may not have yet reached equilibrium. Therefore, the hydraulic heads (or water levels) presented in the results of transient simulations may continue to change with time after the end of the simulation period.

8.1 Northern Pumping Area Predictive Simulations

For this simulation, a total of 10 hypothetical production wells were included in the model in two rows extending northward from Villanueva, generally along the alignment of the railroad (Figure C-7). Each well was assigned a pumping rate of approximately 383 gpm, with all production



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BROWN AND CALDWELL
Carson City, Nevada

Figure C-7

North Wells Predictive Simulation Groundwater Elevation Contours Simulation Year 20

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from model Layer 2. The first well was turned on for year one of the 25-year simulation, the second well was turned on in year two of the simulation, and additional wells were turned on at two-year intervals thereafter. The last well was turned on in year 18 of the simulation. Once a well was turned on, it continued to pump for the duration of the simulation. Model-predicted water levels are presented for year 20 of the simulation in Figure C-7 and for year 25 of the simulation in Figure C-8.

Although each of the hypothetical wells was assigned a pumping rate of approximately 383 gpm in this simulation, the aquifer may not yield this amount to an individual well in the area north of Villanueva. Therefore, the actual number of wells required to achieve the additional 3,640 gpm of groundwater production will likely be greater than 10.

The simulation results indicate that the aquifer drawdown in the vicinity of the hypothetical wells located north of Villanueva would be approximately 12 meters at the end of 20-years (Figure C-9). An additional 3 meters of drawdown is predicted by year 25 of the simulation (Figure C-10).

8.2 Southern Pumping Area Predictive Simulations

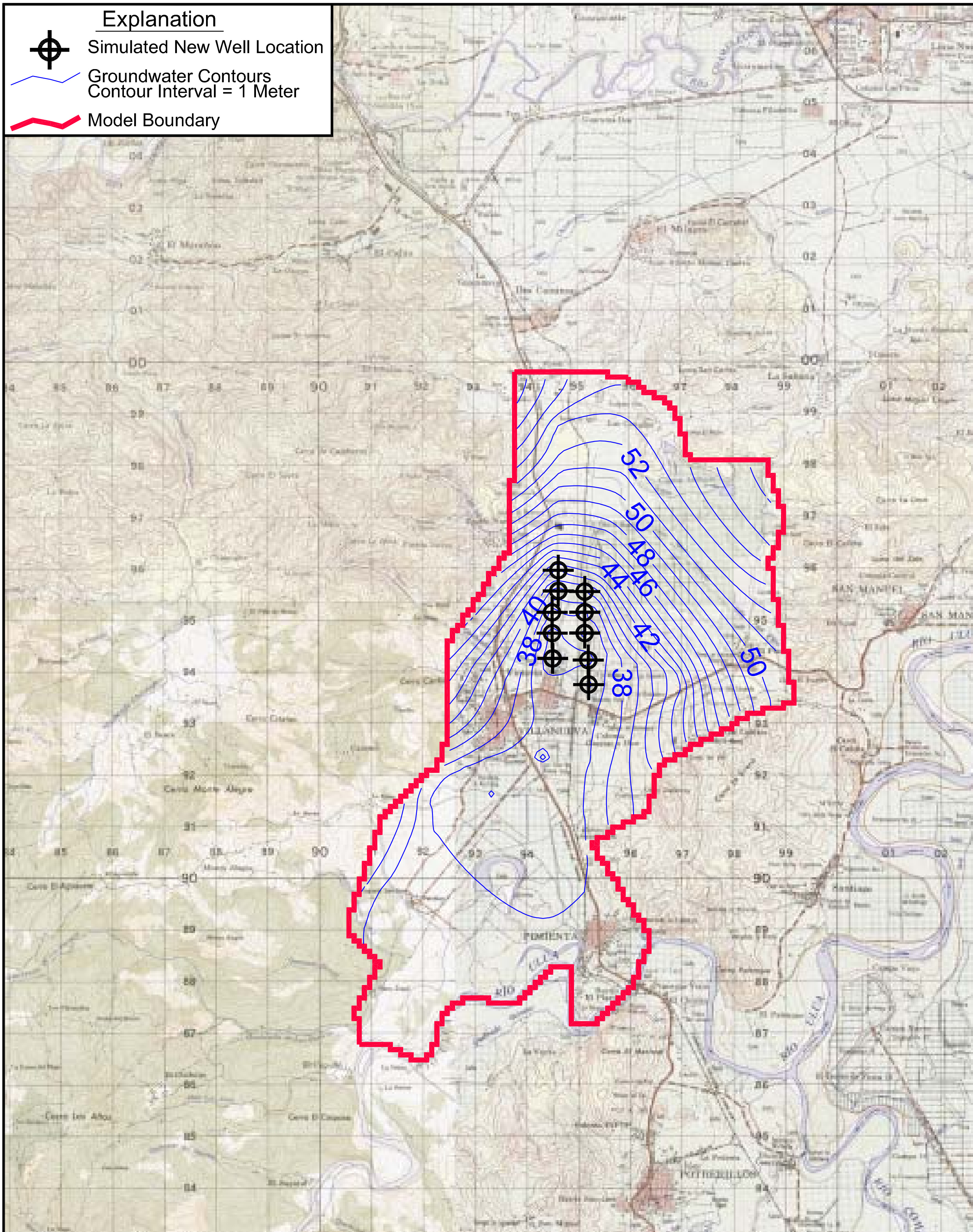
For this simulation, a total of 6 hypothetical production wells were included in the model in two rows extending southward from Villanueva, just to the east of the existing cane field wells (Figure C-11). Each well was assigned a pumping rate of approximately 606 gpm, again with all production from model Layer 2. The first well was turned on for year one of the simulation, and then another well was turned on every four years through year 17 of the simulation. The final well was turned on in year 20 of the simulation. As in the other predictive simulation, once a well was turned on, it continued to pump for the duration of the simulation. Model-predicted water levels are presented for year 20 of the simulation in Figure C-11 and for year 25 of the simulation in Figure C-12.

The performance of the existing wells in the cane fields area indicates that new wells located in this area would likely produce at the rate assigned in the predictive simulation. The higher aquifer transmissivity in this area would also likely allow for closer spacing of production wells.

The simulation results (Figure C-13) indicate that the aquifer drawdown would be approximately 5 meters in the cane fields area at the end of the 20-year simulation period. An additional meter of drawdown is predicted by year 25 of the simulation (Figure C-14).

The reasons that the aquifer drawdown is less in the southern well pumping simulation than in the northern well pumping simulation include:

- The aquifer transmissivity in the southern area is considerably greater than in the northern area, and;
- the proximity of the southern pumping area drawdown to the Ulua River induces groundwater flow from the constant head model boundary simulating the Ulua River.



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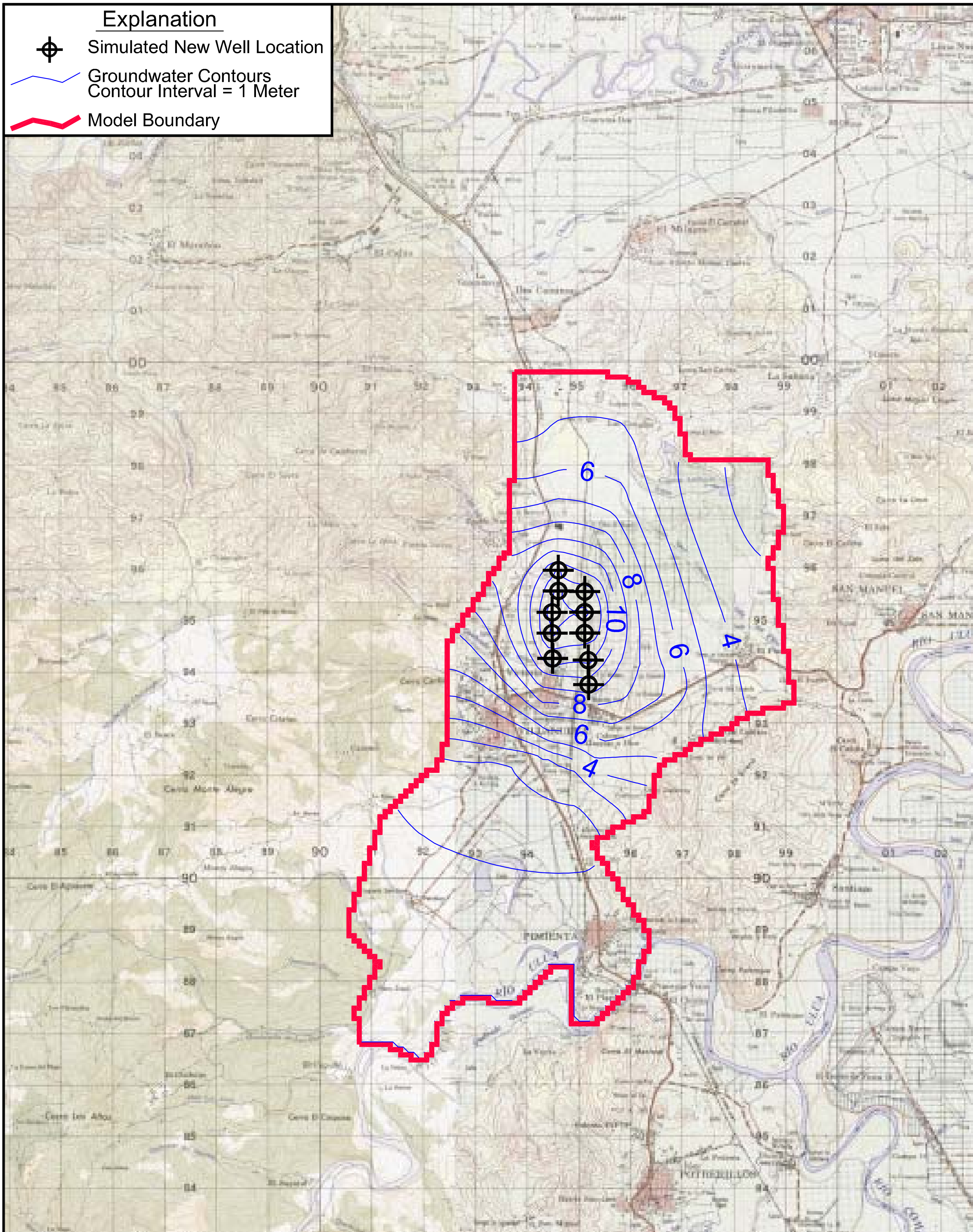
BROWN AND CALDWELL
Carson City, Nevada

Figure C-8

North Wells Predictive Simulation
Groundwater Elevation Contours
Simulation Year 25



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BROWN AND CALDWELL
Carson City, Nevada

Figure C-9

North Wells Predictive Simulation Drawdown Contours Simulation Year 20

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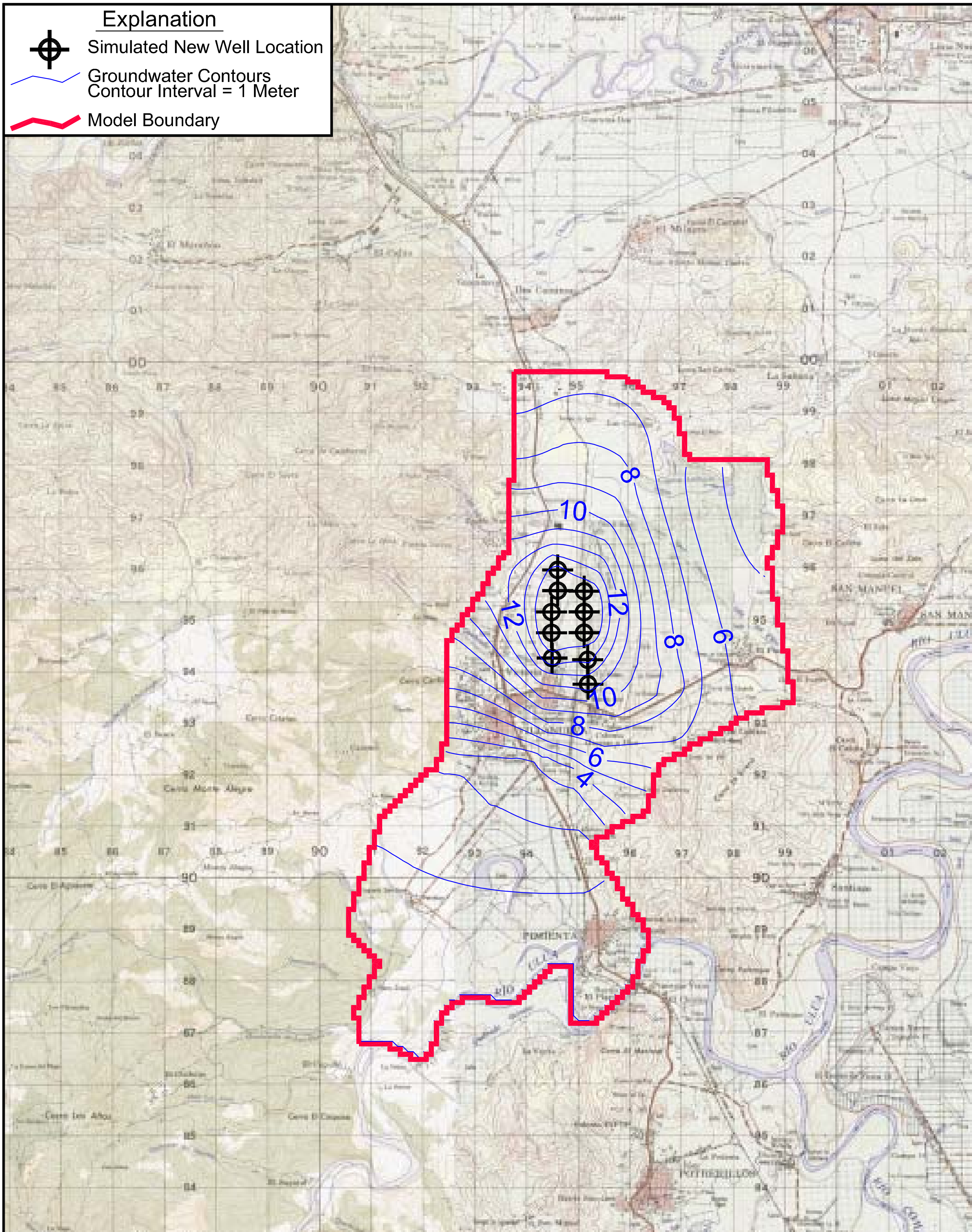

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BROWN AND CALDWELL
Carson City, Nevada

Figure C-10

North Wells Predictive Simulation
Drawdown Contours
Simulation Year 25

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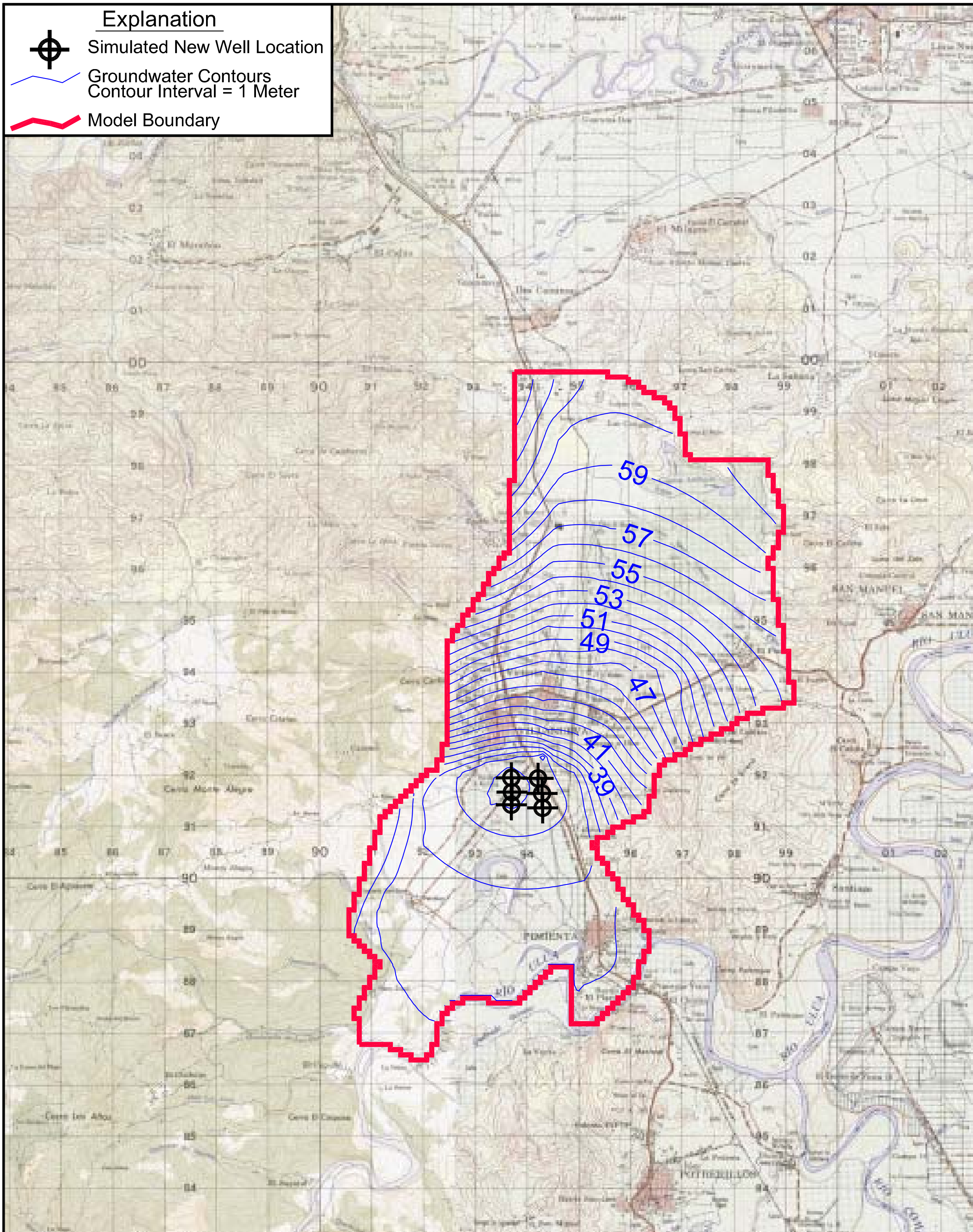

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BROWN AND CALDWELL
Carson City, Nevada

Figure C-11

South Wells Predictive Simulation
Groundwater Elevation Contours
Simulation Year 20

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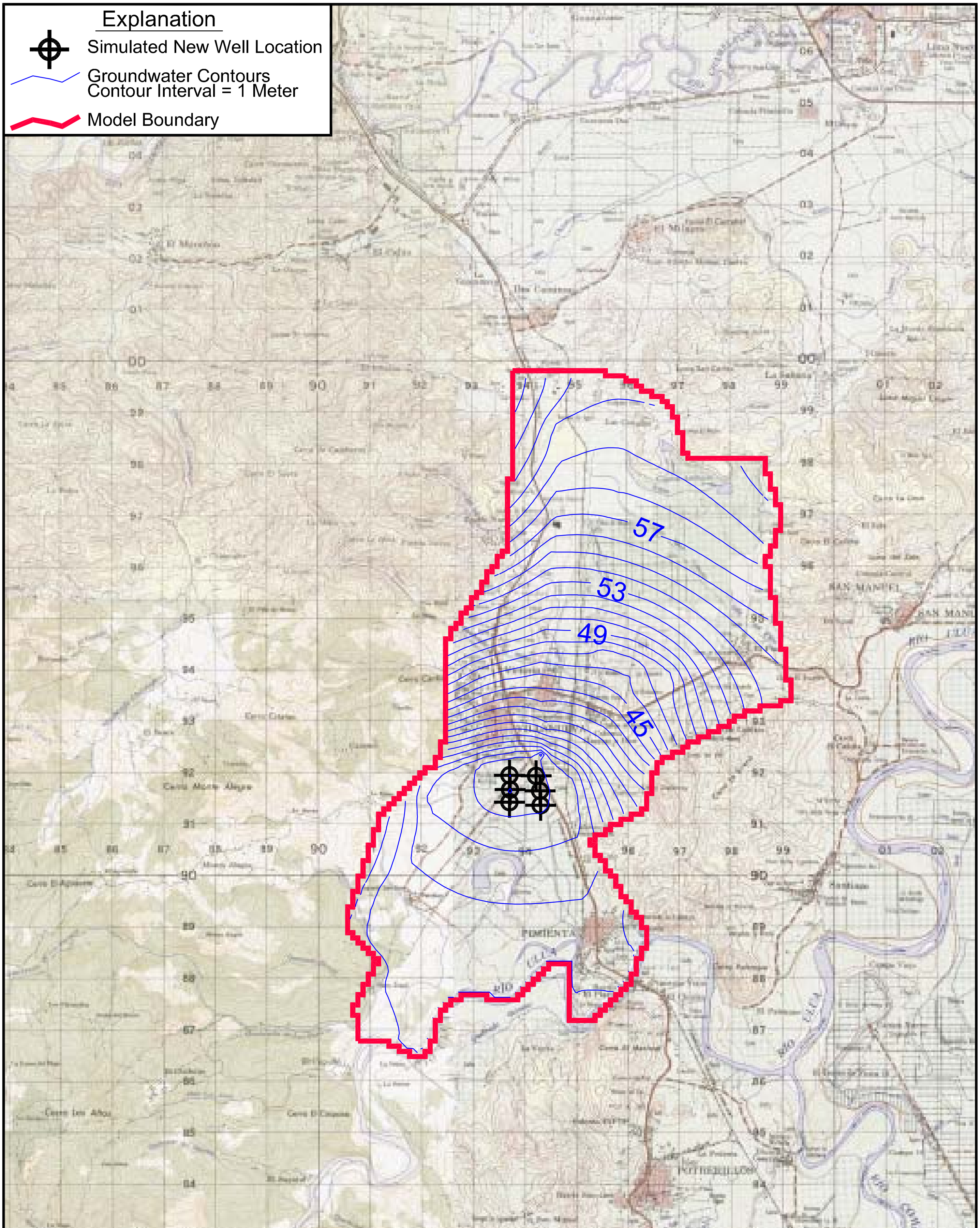

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BROWN AND CALDWELL
Carson City, Nevada

Figure C-12

South Wells Predictive Simulation
Groundwater Elevation Contours
Simulation Year 25

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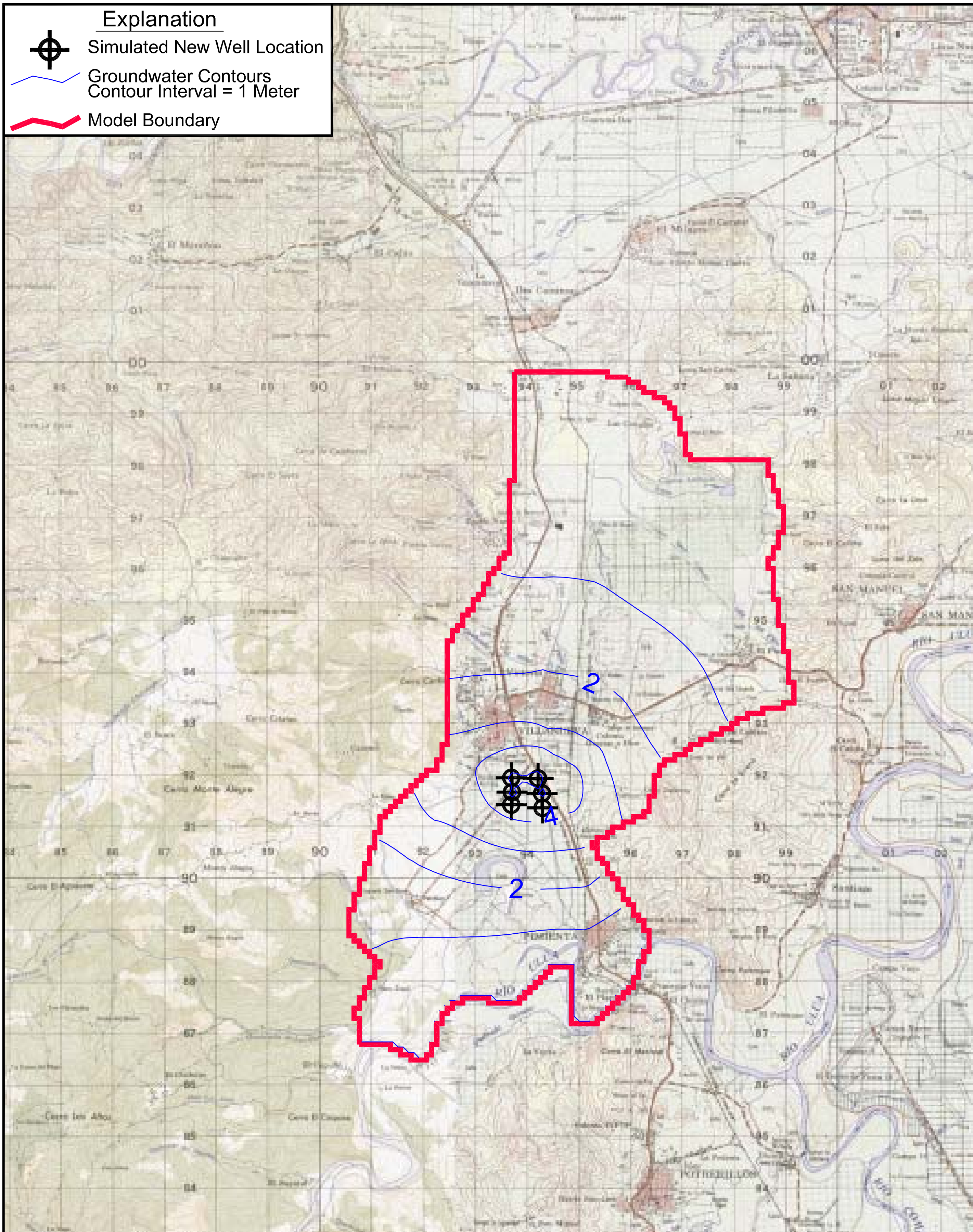

DATE:	PROJECT NUMBER:	SCALE:		
Mar. 2002	21143	0 1000 2000 SCALE IN METERS		**Figure C-13** **South Wells Predictive Simulation Drawdown Contours Simulation Year 20**

BROWN AND CALDWELL
Carson City, Nevada

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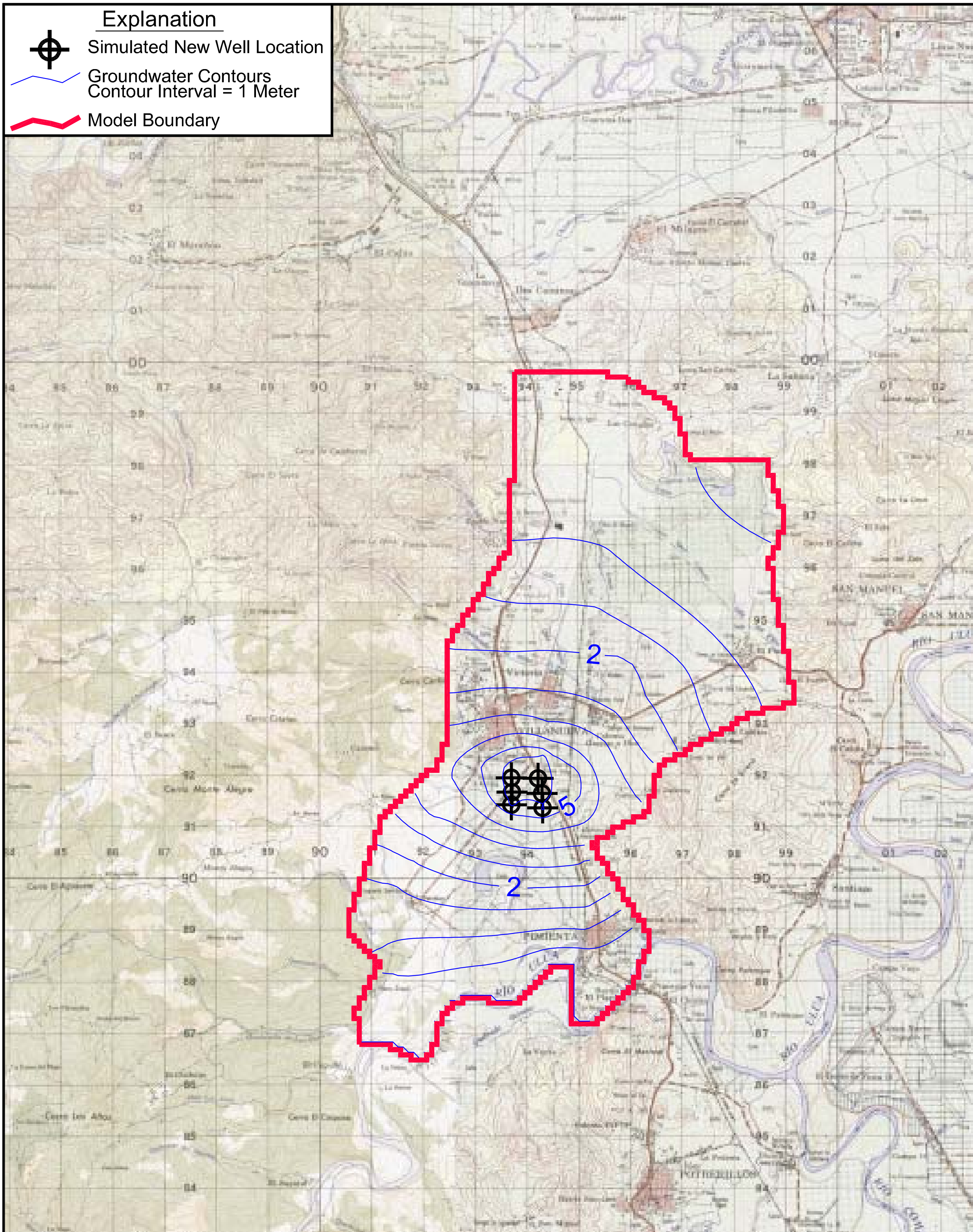

DATE:	PROJECT NUMBER:	SCALE:		
Mar. 2002	21143	0 1000 2000 SCALE IN METERS		**Figure C-14** **South Wells Predictive Simulation** **Drawdown Contours** **Simulation Year 25**
BROWN AND CALDWELL **Carson City, Nevada**				

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Aquifer drawdown created by the southern area pumping simulation may be somewhat greater than predicted by the model because of the constant head boundary condition. If the simulated head in the adjacent aquifer is lower than the constant head boundary, the constant head boundary responds by supplying water to the simulated aquifer. No drawdown can occur at the constant head boundary. Thus, the greater the gradient between the constant head boundary and the simulated aquifer, the greater the flow of water from the constant head boundary will be. The Ulua River will likely not behave as an ideal constant head boundary, but will instead contribute some water to the Villanueva Valley aquifer system. Additional groundwater may be induced to flow into the Villanueva Valley aquifer system from aquifers located south of the Ulua River. The extent to which the Ulua River actually behaves as a constant head boundary is unknown, and may only be determined through long-term monitoring.

Although the actual aquifer drawdown created by increased pumping in the southern area may be somewhat underestimated by the model, it will most likely remain significantly less than that created by increased pumping in the northern area. New wells located in the southern area are also far more likely to have higher groundwater production rates, and the higher aquifer transmissivity will allow for closer well spacing.

9.0 SUMMARY AND CONCLUSIONS

The conceptual model for Villanueva was developed based on the understanding that the upland areas surrounding Villanueva serve as the major source of recharge for surface and groundwater in the municipality. The model was also supplemented with information resulting from analysis of five new wells installed by Brown and Caldwell.

The conceptual groundwater budget indicates that of the estimated 4,300 gpm that enters the Villanueva Valley aquifers through mountain front and aerial recharge, approximately 2,200 gpm is currently extracted by production wells and approximately 2,000 gpm flows to the Ulua River. This result suggests that the current estimated extraction rate could be increased 4,300 gpm (a rate approximately equal to the estimated aquifer recharge total) on a long-term, continuous basis before groundwater discharge from the Villanueva Valley aquifer system to the Ulua River stops.

Transient model simulations indicate that it is possible to increase groundwater production in the Villanueva Valley to 5,900 gpm, although this magnitude of production increase will cause significant changes in the groundwater flow system underlying the valley. The transient simulations also show that the area to the south of Villanueva is the best location for additional production wells. New wells located south of Villanueva can be spaced more closely, will likely produce more water per well, and will create less aquifer drawdown.

The area to the north of Villanueva is less favorable for the location of new production wells. New wells located north of Villanueva will likely produce less water per well, and thus increase the number of new wells needed to meet demand. The predicted aquifer drawdown created by increased pumping north of Villanueva is significant enough to impact existing production wells and potentially significant enough to cause aquifer compaction and ground surface settlement.

10.0 REFERENCES

Anderson and Woessner, 1992. Applied Groundwater Modeling, Simulation of Flow and Advective Transport, Academic Press, 1992.

Environmental Simulations, Inc., 1997, Groundwater Vistas.

McDonald M.G. and Harbaugh, A.W. 1988. A Modular Three-Dimensional Finite-Difference Groundwater Flow Model, United States Geological Survey Techniques of Water-Resources Investigations, Book 6, Chapter A-1.

APPENDIX D

Water Resources Management System Users Guide

WATER RESOURCES MANAGEMENT SYSTEM USER'S GUIDE

Villanueva, Honduras

June 2002

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1.0 INTRODUCTION

The Water Resources Management System (WRMS) is a desktop computer application developed to store, manage, and analyze technical information gathered and generated for this project. The application is a management tool that can be used by the municipalities and other decision-makers to sustain and manage their groundwater resources. The system is composed of both a data management system and a geographic information system linked together as one application. Through the WRMS, users can:

- Manage and generate reports for wells, storage tanks, and springs
- View well logs and well completion diagrams
- Analyze water quality and water level data
- Track statistics on water use
- View wells, water quality information, and aquifer characteristics on maps of the study area
- Identify and prioritize future well sites

The application consists of two primary components; a data management system and a geographic information system (GIS). The application is written so that the two components work together and function as one system. Data are shared back and fourth between the data management system and the GIS.

1.1 Overview

The WRMS consolidates the most critical water resource information for a municipality. It provides a central place to manage, analyze, and display water resource information in both map and tabular form. The WRMS accommodates all major types of information needed for sound water resource management including data on wells and other water sources, future demand and growth, infrastructure and organizational boundaries, and water quality and aquifer characteristics.

Because the system is designed to accommodate additional data as more information is collected and wells are created or modified in the future, it can be used to facilitate sound water resource decision-making in the future. Is easy to use and requires minimal training, which will facilitate continued system use. It uses a standard methodology for identifying and prioritizing future well sites, which will allow municipalities to continue to apply a consistent planning approach.

The WRMS is designed to work in conjunction with the findings of the Water Resources Management Report. Most of the data collected or developed for the report are contained in this system, and are available for further analysis, display, and incorporation with new data as it is collected. The system can be used to view and explore additional details of the existing water system, as well as explore in detail the conceptual model of the aquifer system and the groundwater modeling results.

The WRMS should be used to provide a common environment for communication among stakeholder agencies for water resource planning. The system provides a consistent view and methodology for analyzing water resource data. Consistently using it as a communication tool among stake-holders will make the sometimes confusing and complex technical information easier to understand. New data, such as new wells, additional sampling results, or new water level measurements should be entered into the system in order to have the most up-to-date information available for decision-making.

1.2 How to Use the Manual

This manual is divided into two parts:

- **Users Guide** – This section describes the application and use of the system from the users perspective. It explains the functionality of the system, presents step-by-step instructions for adding and managing data, creating reports, generating maps, and using the analysis tools. Anyone who needs to use the system should read this section to find the proper procedures for adding, managing, and analyzing data.

- **Administrators Guide** – This section describes the operation of the system and covers the procedures necessary to keep the system functioning properly. It is written for the person who is responsible for making sure the system is configured and operating properly.

2.0 USER GUIDE

This section explains how the system can be used to manage, analyze, and report on water resource data. First the organization of the data will be discussed, and then an overview of the functionality of the interface will be explained. Finally, the user will be walked through a series of common tasks that are typically performed using the system.

2.1 Data Organization

Figure 2-1 shows how the data are organized in the WRMS. The data organization is presented in a hierarchy shown on the left. The types of data collected at each level are shown on the right. The highest level of data is at the Municipality level. All other data entered into the system will be associated with a Municipality. Information collected at this level includes map data in the GIS system and pre capita growth/water consumption statistics for each municipality.

Within each municipality, there will be one or more service areas. A service area is a self-contained portion of the distribution system. It is comprised of wells, storage tanks, piping, and other infrastructure designed to supply a specific portion of the municipality. Typically, it is self-contained, with its own operating characteristics[1]. The user can store water usage information for each storage area (e.g. population served, pressure, and water usage).

Within each service area, there may be one or more wells and storage tanks. Most of the information stored in the WRMS is related to wells. For each well, its construction, location, and operational specifications can be stored. Water sample records and water level records can be entered, and scanned images can be loaded (e.g. well completion diagrams, photographs, and well logs). For storage tanks, operational and construction specifications can be entered.

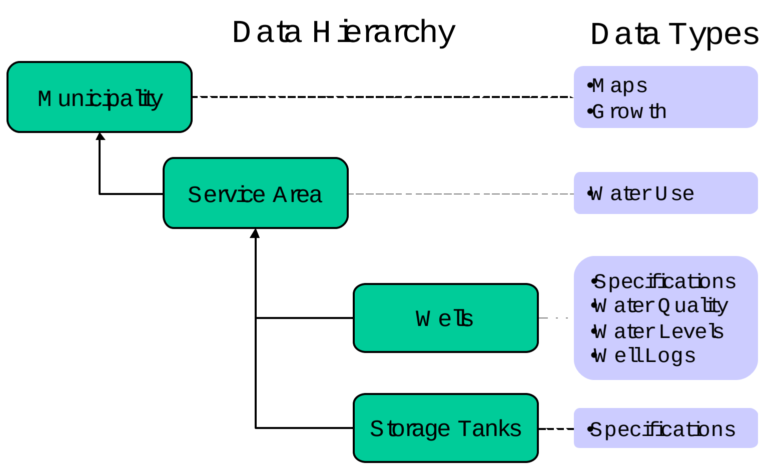

Figure 2-1. Data Organization

[1] This system is delivered with one service area defined for each municipality, which may or may not reflect the actual service area configuration for each municipality. The WRMS will work fine without changing this, however, the capability of redefining the service areas to more accurately reflect the conditions of each municipality is available. See Entering Infrastructure Data for more details.

2.2 User Interface

Once the application is started, the user is presented with a variety of options via the Main Menu at the top left-hand corner of the screen.

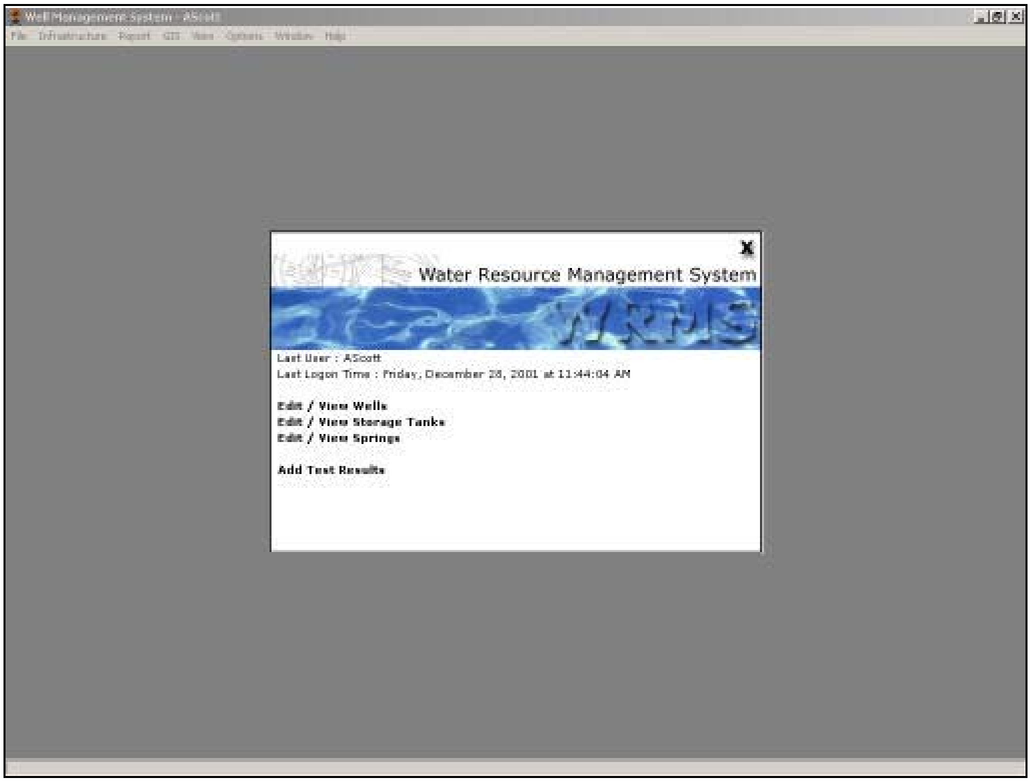

Figure 2-2. Startup Screen

The options available are:

- **FILE** – Exit the application.
- **INFRASTRUCTURE** – Used to manage data for the municipality, service areas, wells, and storage tanks.
- **REPORT** – Used to run reports and graphs for selected infrastructure data.
- **GIS** – Opens ArcView® to create maps or run the Well Site Prioritization tool.
- **VIEW** – Opens the USGS Database or the Water Resources Management Plan report.
- **OPTIONS** – Mostly an administrative area, it is where the user can change the language or to manage system configuration.
- **WINDOW** – Used to manage different application windows that are opened.
- **HELP** – Opens the help file for the WRMS.

2.3 Interface Terms

The following figure shows a typical interface screen and its components. The system functionality is selected via the **MAIN MENU** shown at the upper left-hand portion of the screen. Infrastructure components are navigated via the **DATA TREE** on the left. The **DATA TREE** allows the user to navigate through the infrastructure hierarchy. For example, each **MUNICIPALITY** contains a

SERVICE AREA, and each **SERVICE AREA** contains **WELLS** and **STORAGE TANKS**. Each element in the tree has a '+' box associated with it. Clicking on the '+' expands that branch of the tree. For example, clicking on the '+' next to **WELLS** opens a list of all wells within the selected **SERVICE AREA**. When the branch is expanded, the '+' symbol turns into a '-' symbol. Close the branch by clicking on the '-'. By expanding and contracting each branch, the user can quickly navigate to the desired information.

The area on the right is used to present information about the selected infrastructure element. In this example, the data entry screen for Well LC-1 is shown. This screen is composed of the following kinds of elements:

- **TEXT BOX**: Used for entering free-form text.
- **PICK LIST**: Used to make a select from a list. The lists are managed under **VALID VALUES** in the **OPTIONS** menu selection. See the Administrators Guide for more information.
- **CHECK BOX**: Represents a Yes (if checked) or No (if unchecked).
- **BUTTON**: Click on the button to initiate an action (e.g. Close the window, save data, etc.).

This terminology will be used throughout this Users Guide.

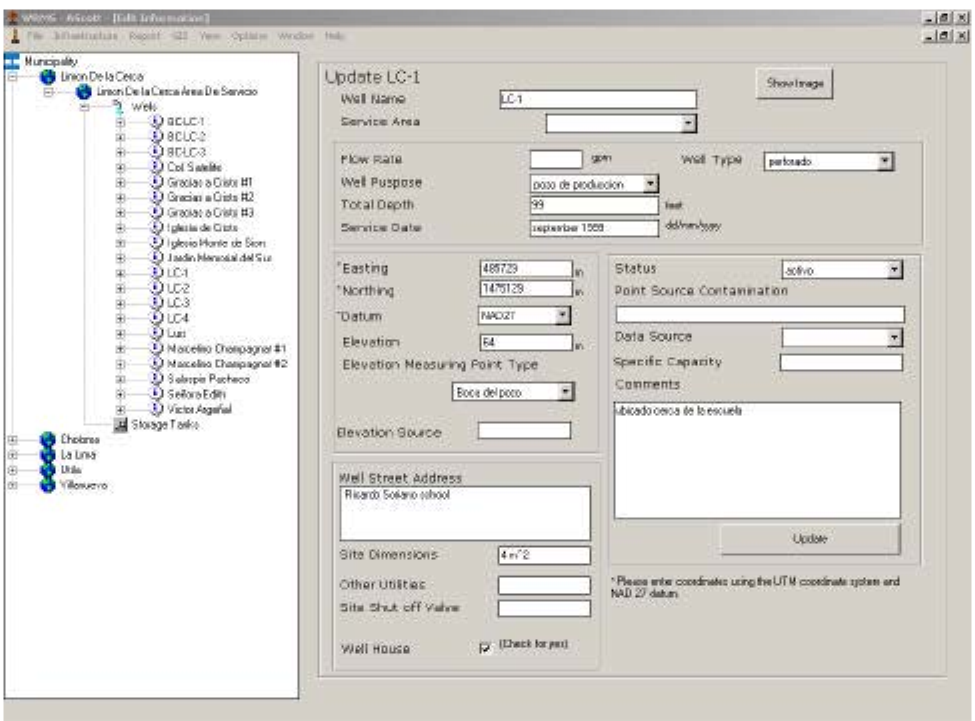

Figure 2-3. Interface Terms

Two additional terms are needed associated with the mouse-pointing device:

- **CLICK** – When instructed to click on something, point the arrow on the screen over the object and click the *left* mouse button.

- **RIGHT-CLICK** – When instructed to right-click, point the arrow on the screen over the object and click the *right* mouse button.

2.4 Common Tasks

This section describes the common tasks that can be performed using the WRMS. These are:

- Opening the application – How to start the WRMS.
- Changing the Interface Language – The WRMS interface can be translated between Spanish and English.
- Managing Infrastructure Data – Entering and managing data related to Municipalities, Service Areas, Wells, and Storage Tanks.
- Creating Reports – Generating standard reports for infrastructure data.
- Map Analysis – Using ArcView® to generate maps.
- Well Site Prioritization – Using the well site prioritization decision-support tool.
- Assessing Related Information – Opening up other applications.
- Getting Help – Accessing this manual on-line.

2.4.1 Opening the Application. This application comes already installed on the computers provided. To start the WRMS, do the following:

1. Click on the **START** button in the bottom left-hand corner of the screen to open the system menu.
2. Click on **PROGRAMS**. This will open a sub-menu of available programs and program folders
3. Click on on **WRMS**. The application will open when WRMS is clicked.

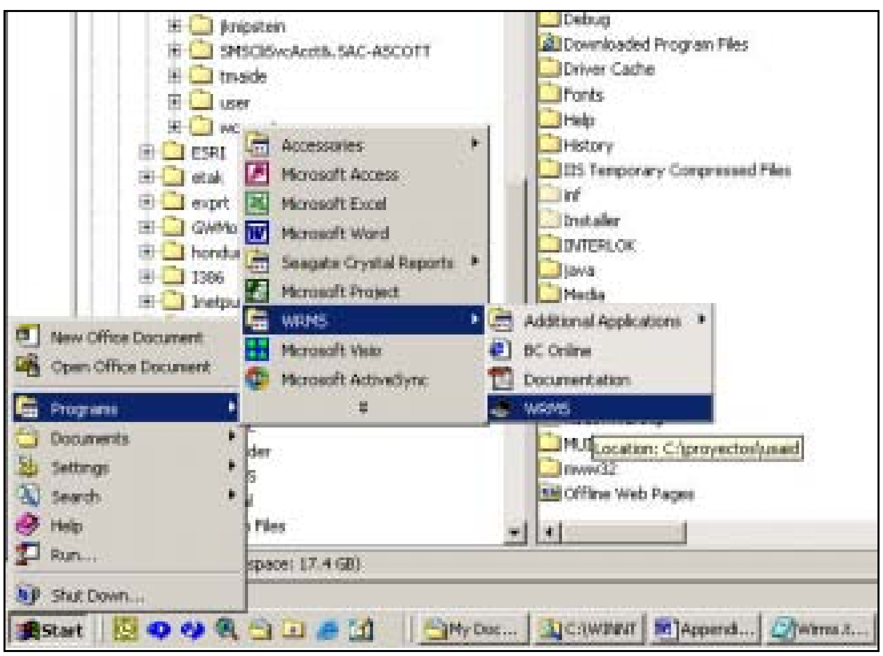

Figure 2-4. Starting the WRMS

2.4.2 Changing the Interface Language. The user may change the language used in the WRMS interface. To do this:

1. Click on **OPTIONS** from the menu. A sub-menu will appear.
2. Click on language from the sub-menu.
3. A pop window will appear with a list of available languages. Select the language desired and click **OK**.

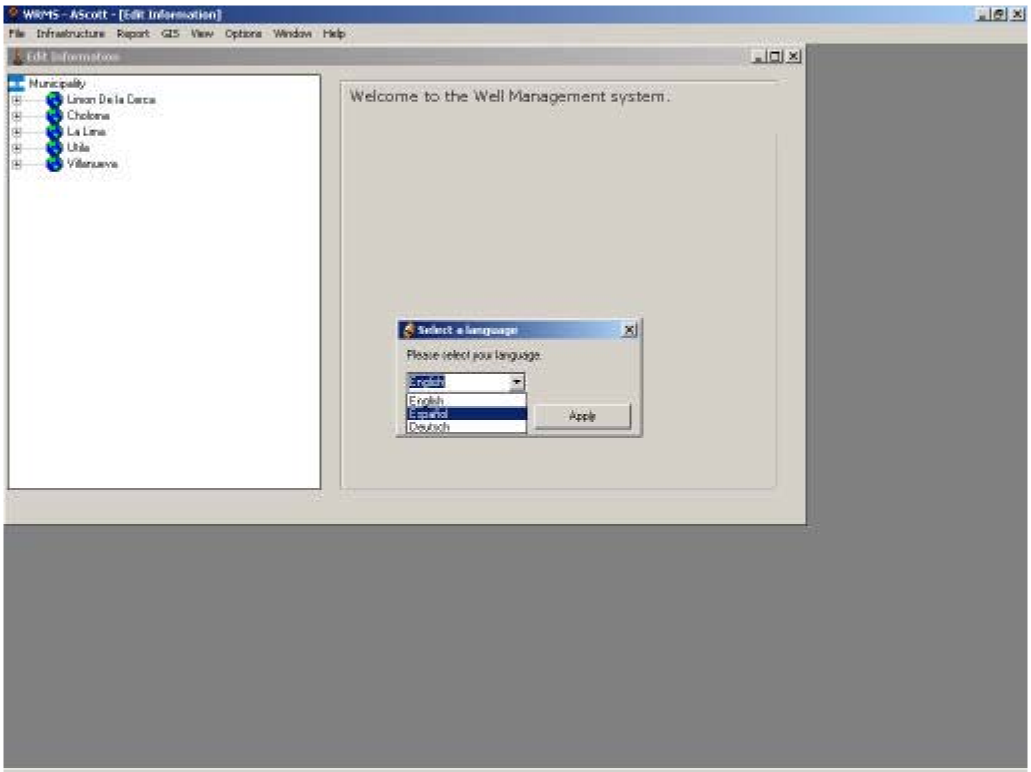

Figure 2-5. Changing the Language

The interface will be translated into the selected language.

Note: It may be necessary to close a window and re-open it for the translation to take effect. Also, if a phrase is not translated, it means that the translation has not been entered into the translation database. Please see the Administrators Guide for the steps to add a new translation.

2.4.3 Managing Infrastructure Data. Infrastructure data includes information on municipalities, service areas, wells, and storage tanks. These data are organized in a hierarchy in the database (see Data Organization, above) and are presented the same way in the user interface. To access the data entry and management screens:

1. Click on **INFRASTRUCTURE** from the **MAIN MENU**. A sub-menu for **WELLS** and **STORAGE TANKS** will appear.
2. Click on **WELLS** or **STORAGE TANKS**.

Selecting **WELLS** or **STORAGE TANKS** will open the **DATA TREE** and expand the desired branch of information. The first element of the desired type (either the first well or first storage tank) will be shown, presenting the general information for that particular record on the right. The user may then change or review any of the information associated. If data are changed, click on the **UPDATE** button to save the changes.

To navigate through the data, click on the desired branch. The branch will expand to the next level, allowing the user to view its contents. Depending upon the level selected, a data form will appear on the right. The table below shows the information provided at each level.

Table 2-1. Data Screens for Each Level

Level	Data Shown
Municipality	Growth and Water Consumption
Service Area	Service Area Characteristics
Wells	Well Depth Graph
Individual Wells	Well General Information
Individual Storage Tanks	Storage Tank General Information

2.4.3.1 Municipalities. Municipalities are the study areas defined for this project. Typically, they incorporate the urban and developed areas of a community, but may not include the entire municipal boundary. When a **MUNICIPALITY** is selected from the **DATA TREE**, water consumption data will be shown on the right. This is a simple table showing per-capita consumption per year. To enter a new record, click on the empty row on the bottom of the table. Enter the year, estimated population, and the average per-capita water consumption in gallons per day per person. The table can accommodate historical data as well as predicted growth. This information enables the user to view expected water consumption patterns over time.

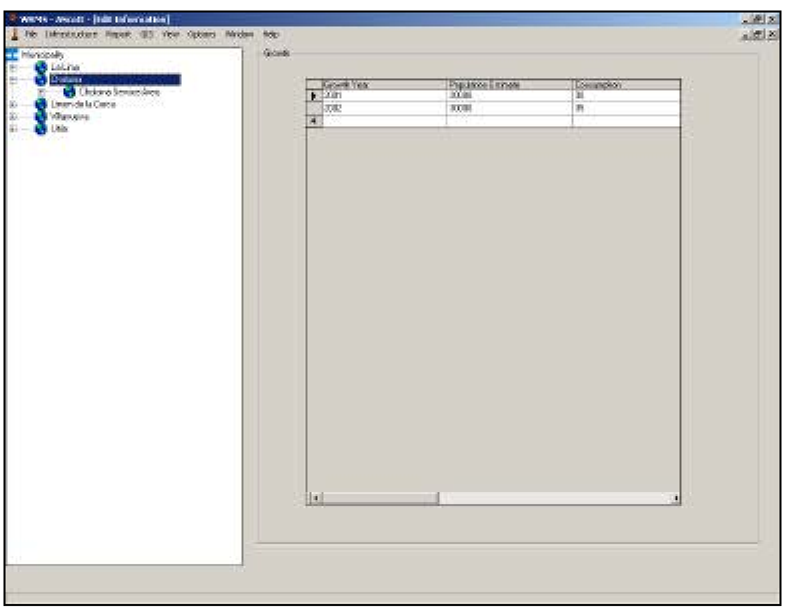

Figure 2-6. Predicted Growth Data Screen

2.4.3.2 <u>Service Areas.</u> To create a new **SERVICE AREA** for a **MUNICIPALITY**:

1. Click on the **MUNICIPALITY** desired, then right-click to bring up a popup menu.
2. Select **ADD SERVICE AREA**. A blank service area form will appear.

Enter the service area name and other data as desired, then click **UPDATE**. The **DATA TREE** will insert the new **SERVICE AREA**.

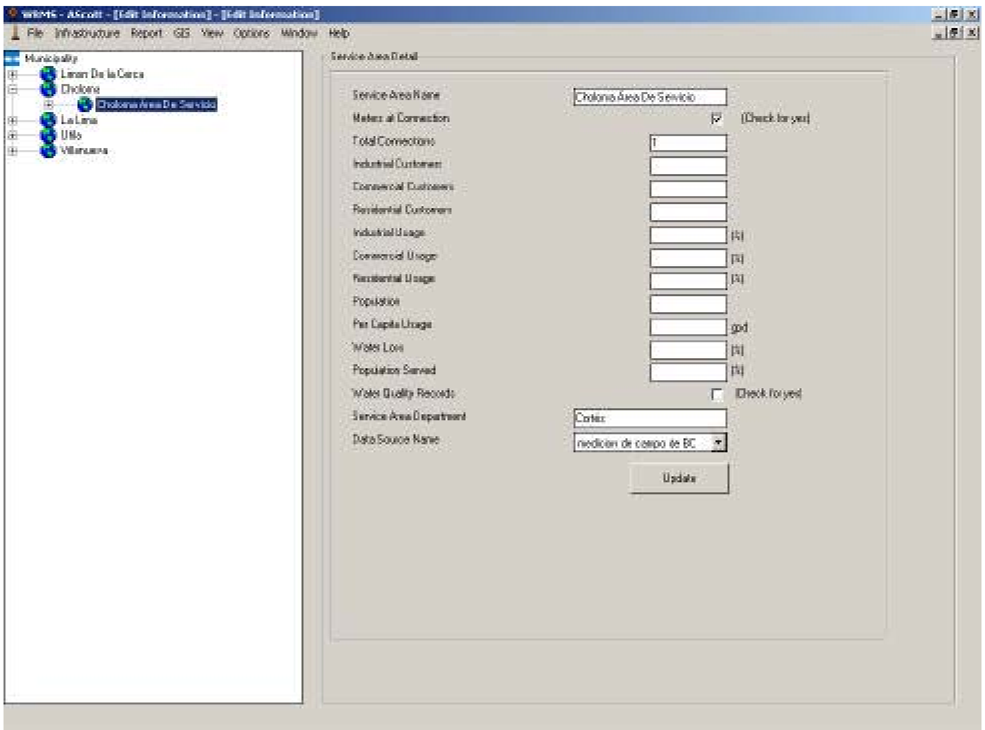

Figure 2-7. Service Area Data Screen

Clicking on an existing **SERVICE AREA** brings up a form displaying water consumption information for the area selected. This information can be entered for each service area for quick reference when evaluating service area needs. The following table describes the service area information:

Table 2-2. Service Area Data

Data Field	Description
Service Area Name	Enter the name of the Service Area
Meters at Connection (yes/no)	Check **YES** if present
Total Connections	Enter number
Industrial Customers (number)	Enter number
Commercial Customers (number)	Enter number
Residential Customers (number)	Enter number
Industrial Usage	Percent of total usage
Commercial Usage	Percent of total usage
Residential Usage	Percent of total usage

Data Field	Description
Per Capita Usage	Gallons per person per day
Percent Water Loss	Percent of total production
Percent Population Served	Percent of total service area population
Water Quality Records?	Check if water quality records are available
Service Area Municipality	Pick municipality name from pick list
Service Area Department	Pick department name from pick list
Data Source	Select data source. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.

2.4.3.3 Wells. To add a new well to a service area:

Click on the desired **SERVICE AREA** and right-click the mouse. A pop-up menu will appear.

Select **ADD WELL TO SERVICE AREA**. A blank entry form will appear. Enter the new well name and it will be added.

Click on the desired data field and enter the desired information. Click on the **UPDATE** button to save. The new well will be added to the database.

2.4.3.4 General Information. Clicking on a **SERVICE AREA** opens up two additional branches: **WELLS** and **STORAGE TANKS**. Clicking on **WELLS** will expand that branch to show all the wells associated with the service area. Clicking on an individual **WELL** opens the general information form for the well.

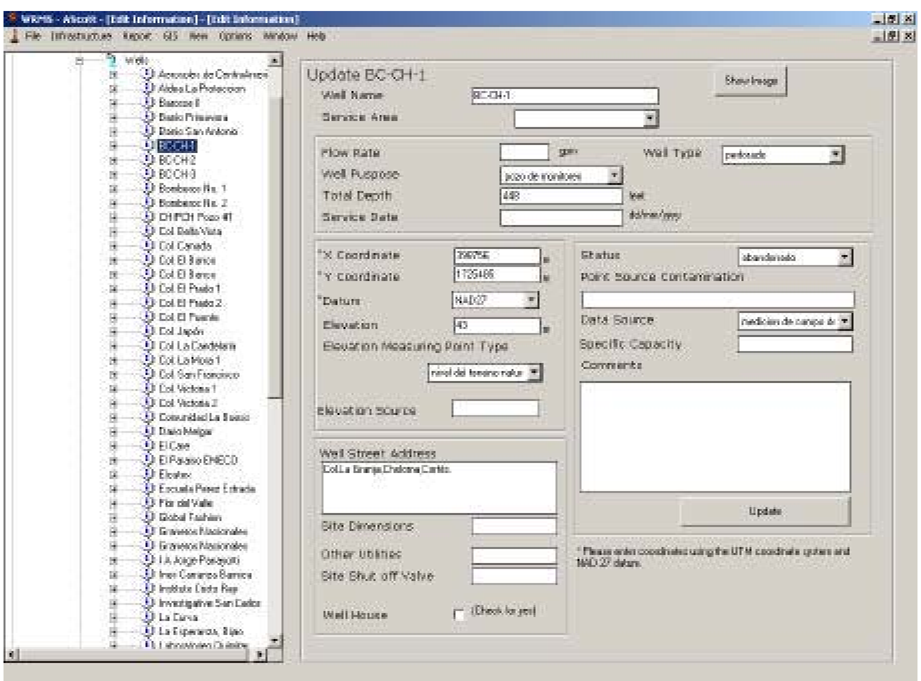

Figure 2-8. Well General Information

The table below describes the data fields available in the **WELL GENERAL INFORMATION** screen.

Table 2-3. Well General Information Data Fields

Data Field	Description
Well Name	Name of the well
Assign a New Service Area	Use the pick list to assign the well to a new service area
Flow Rate	Enter the flow rate in gallons per minute
Well Purpose	Select the purpose of the well from the list
Total Depth	Enter the total well depth in feet
Service Date	Enter the date the well went into service
Well Type	Select the type of well from the list. . If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.
Easting	Enter the easting coordinate in UTM meters, NAD27
Northing	Enter the northing coordinate in UTM meters, NAD 27
Datum	Select the datum used. If not known select unknown.
Elevation	Enter the well elevation in meters
Elevation Measuring Point Type	Select the type from the list
Elevation Source	Enter source (GPS, survey, map coordinates, etc.)
Well Street Address	Enter address, if known
Site Dimensions	Enter dimensions of site
Other Utilities	Enter other utilities present on site
Site Shut off valve	If present, describe location
Well House	Check if present
Status	Select current status of well from list
Point Source Contamination	List any potential contamination sources present
Data Source	Select data source of this information
Specific Capacity	Enter specific capacity of the well
Comments	Any additional information can go here.

Once data edits are complete, click on the **UPDATE** button to save changes.

Note: Coordinate must be entered in UTM meters using the NAD27 datum in order for the location to be properly placed on the GIS map. The user has the option of storing the coordinates using other datum, but these will not show up properly on the GIS map. It is important that these data be recorded accurately and correctly to avoid confusion about their physical locat ion when display with other data.

2.4.3.5 Adding Images. Images and other electronic files, such as .jpg files of well completion diagrams, boring logs, spreadsheets of technical data, and site photographs can be loaded into the database for each well. To load a new image:

1. Click on the **SHOW IMAGES** button. This will open a pop-up window.
2. Click on **ADD**. A file navigation window will appear.

3. Navigate to the desired image or file.
4. Click on the image file and click the **SAVE** button.

If images are already present, they will be shown in the list. Double-click on an image to view it.

2.4.3.6 Construction. Clicking on an individual **WELL** opens these additional options:

- **CONSTRUCTION** – View/edit the well construction details
- **OPERATIONS** – View/edit the well operation details
- **SAMPLES** – View/edit the water quality samples for the well
- **WATER LEVELS** – View/edit the water level data for the well

An empty well construction record is automatically created when a new well is created. To update a construction record for a well:

1. Click on the desired **WELL** so that the **GENERAL INFORMATION** screen is showing,
2. Click **ON WELL CONSTRUCTION** in **THE DATA TREE**. The well construction data screen will appear.

Enter the desired construction data and click the **UPDATE** button. Construction details will be added for the well.

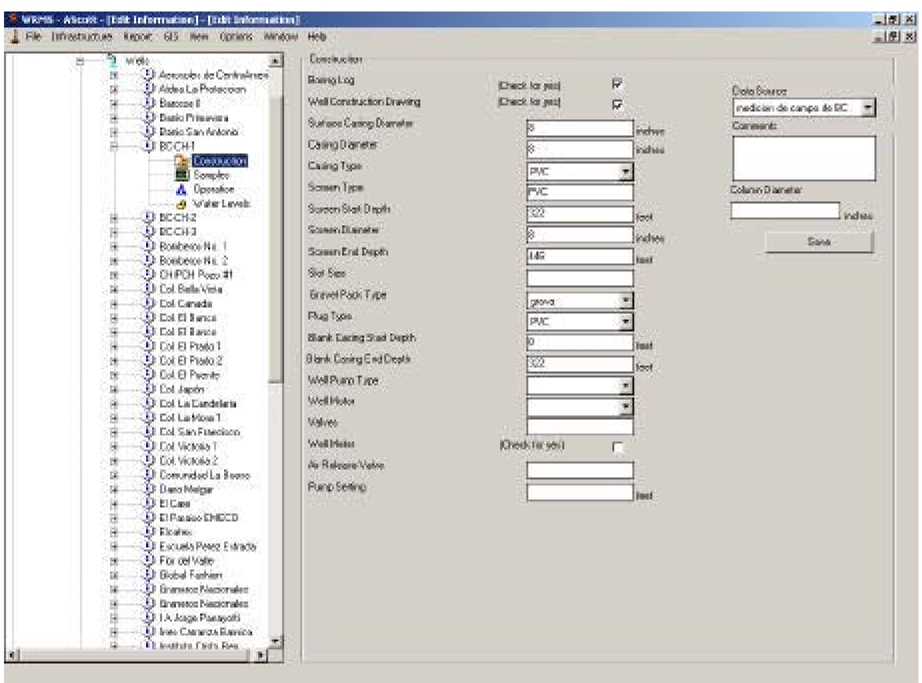

Figure 2-9. Well Construction Details Screen

The table below describes the data fields available in the **WELL CONSTRUCTION** screen.

Table 2-4. Well Construction Data Fields

Data Field	Description
Boring Log	Check (**YES**) if a boring log is available.
Well Construction Drawing	Check (**YES**) if a well construction drawing is available
Surface Casing Diameter	Enter the surface casing diameter if different from the casing diameter, in inches
Casing Diameter	Enter the casing diameter for the well, in inches
Screen Diameter	Enter the screen diameter for the well, in inches
Casing Type	Pick the casing type from the list. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.
Screen Type	Pick the screen type from the list
Screen Start Depth	Enter the start depth, in feet from the ground surface, for the first screen
Screen End Depth	Enter the end depth, in feet from the ground surface, for the last screen
Slot Size	Enter the slot size for the screen
Gravel Pack Type	Pick the gravel pack type from the list
Plug Type	Pick the plug type from the list
Start Casing Depth	Enter the start depth, in feet from the ground surface, for the beginning of the casing
End Casing Depth	Enter the end depth, in feet from the ground surface, for the end of the casing.
Well Pump Type	Pick the type of well pump from the list
Motor	Enter the rating of the motor, in horsepower (hp)
Valves	Enter the types of valves present
Well Meter	Check if the well flow is metered
Air Release Valve	If an air release valve is present, describe
Pump Setting	Enter the depth of the pump setting from the ground surface, in feet
Data Source	Pick the data source for the construction information from the list
Comments	Enter any comments about the well construction
Column Diameter	Enter the column diameter in inches

2.4.3.7 Operation. When a new well is created, an operation record is automatically created for it. To update the data for a well:

1. Click on the desired **WELL** so that the **GENERAL INFORMATION** screen is showing,
2. Click on **OPERATION** in the **DATA TREE**. The well operation data screen will appear.

Enter the desired construction data and click the **UPDATE** button. Operational information will be added for the well.

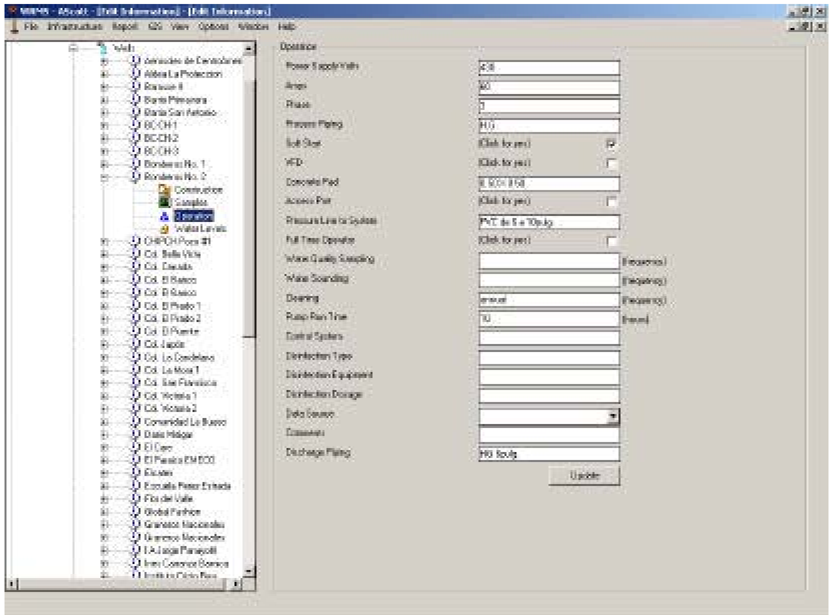

Figure 2-10. Well Operation Data Screen

The table below describes the data fields available in the **WELL OPERATION** screen.

Table 2-5. Well Operation Data Fields

Data Field	Description
Power Supply Volts	Enter the voltage of the power supply
Amps	Enter the amperage of the power supply
Phase	Enter the number of phases for the power supply
Soft Start	Check if a soft start device is present
VFD	Check in a variable flow device is present
Concrete Pad	Describe the concrete pad
Access Port	Check if an access port is present
Pressure Line to System	Describe the line to the system
Full-time Operator (yes/no)	Check (**YES**) if there is a full-time operator at the well
Frequency of Water Quality Sampling	Enter the frequency of water quality sampling (e.g. monthly, semi-annually, etc)
Frequency of Water Sounding	Enter the frequency of water level measurements
Frequency of Cleaning	Enter the frequency of cleaning
Pump Run Time	Enter the number of hours a day the pump is set to run
Control System	Describe the control system, if any
Disinfection (yes/no)	Check (**YES**) if there are any disinfection practices
Disinfection Type	Pick the type of disinfection from the list. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.

Data Field	Description
Disinfection Equipment	Describe disinfection equipment
Disinfection Dosage	Enter the amount, including units (e.g. 10 mg/l)
Data Source	Pick the data source for the construction information from the list
Comments	Enter any additional operation comments
Discharge Piping	Describe the discharge piping

2.4.3.8 Water Quality. Water quality sample results can be stored and viewed for each well. The data are organized by sampling event. Each sampling event must be entered into the system in order to record the resulting water quality. Three types of information are needed to enter water quality information:

- **CHAIN-OF-CUSTODY (COC)** – Information about the form used to describe the sample for the analyzing laboratory.
- **SAMPLE** – The type of sample taken. A COC can contain more than one sample. Multiple samples can be entered for one COC.
- **RESULTS** – The analytical results from the tests performed at the laboratory. Each sample will have one or more test results.

Please see the Sample Manual Reference for more details on water quality sampling procedures.

To enter new water quality sampling results, navigate to the desired well in the **DATA TREE** and click the '+' to open well options. Click on the **SAMPLES** option. An empty grid will be shown on the right like the one below.

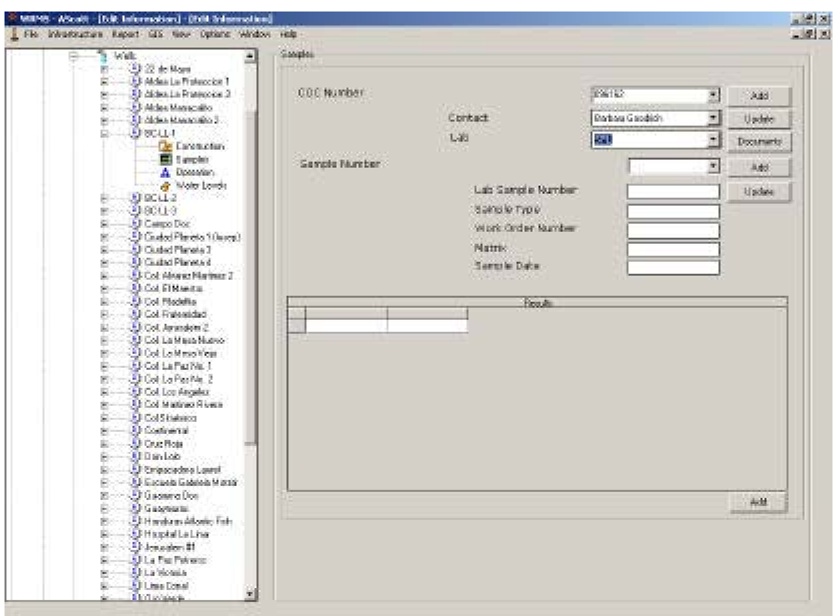

Figure 2-11. Initial Form for Water Quality Samples

Start by entering a new chain-of-custody number. Click on the upper-most **ADD** button. A popup form will appear prompting the user to enter the COC number, sampler, and analytical laboratory. Enter the data and click the **UPDATE** button.

Note: As a best practice, a unique COC number should be present on every chain of custody in order to accurately track and identify the samples when communicating with the laboratory or identify the sample results. A COC number must be entered for each sampling event. If no number is available, create a number that will be unique within the database. A good system, for example, would be to use the following pattern:

UNK-{Well Name}-{DDMMYY}

For well LC1 sampled on October 28, 2001 the COC number would be:

UNK-LC1-281001

By concatenating the well name and the sample date, a unique identifier can be created.

Descriptions of all the COC fields are shown in the table below:

Table 2-6. Chain-of-Custody Data Fields

Data Field	Description
COC Number	Unique chain-of-custody number. See Note describing required COC numbering
Contact	Pick the name of the person in responsible for the sampling. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.
Laboratory Name	Pick the name of the laboratory responsible for the analysis.

Once the COC is created a sample number must be entered. This sample number is the number for the sample identified on the COC. To enter a new sample, click on the second **ADD** button. A popup screen will appear prompting the user for sampling information.

When adding a new sample, make sure that the correct COC is selected. The sample number, sample name, laboratory sample number (enter UNKNOWN if not available) and sample date are required fields. The following table shows the sample data fields.

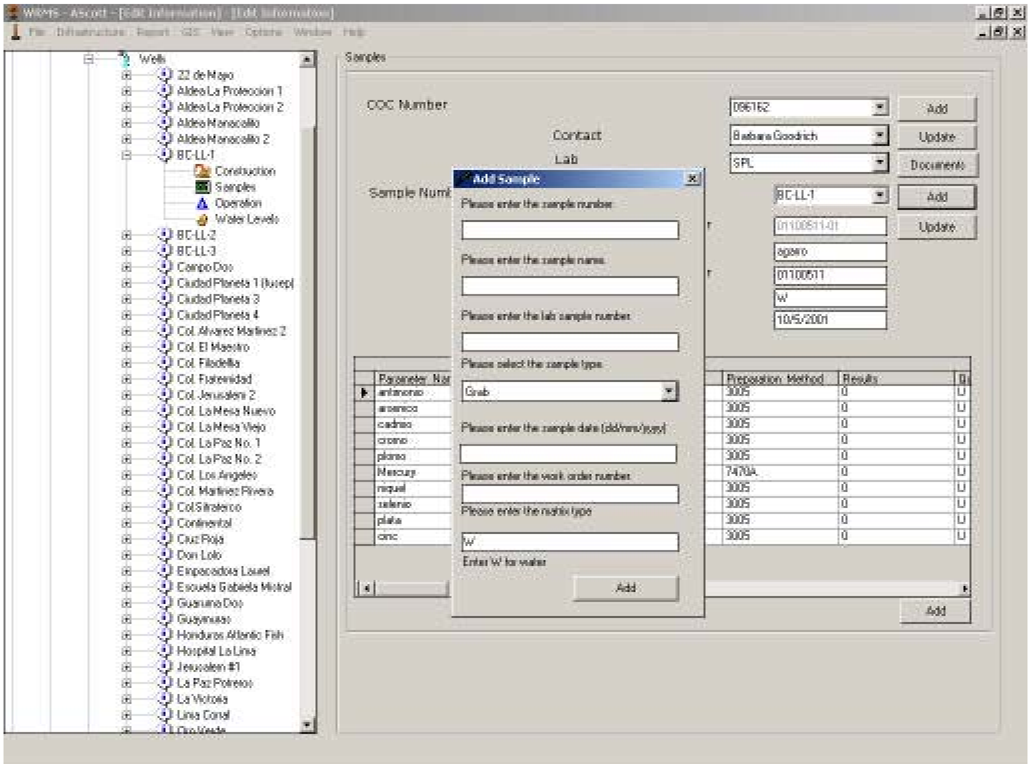

Figure 2-12. Sample Data Entry Screen

Table 2-7. Sample Information Data Fields

Data Field	Description
Sample Number	Designated sample number. This field is required
Sample Name	Name of sample, if used.
Laboratory Sample Number	Sample number designated by the laboratory. Enter UNKNOWN if not available.
Sample Type	Pick the sample type from the list. Grab sample is the most common type
Sample Date	Date sample was taken
Work Order Number	Number of the work order, if used
Matrix	Matrix of the sample. W, or Water, is most common

Once the sample is entered, analytical results can now be entered into the system. To start adding results click the third **ADD** button. A pop-up screen for sample results will be displayed.

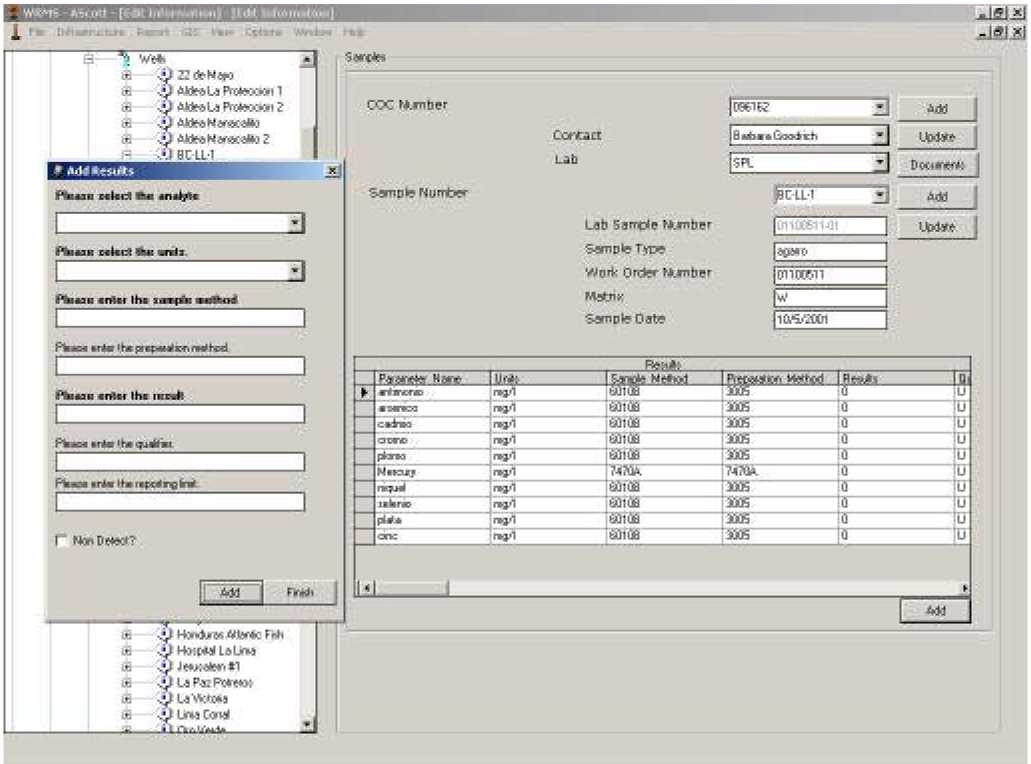

Figure 2-13. Analytical Results Data Entry Screen

The following table shows the results data fields.

Data Field	Description
Analyte Name	Pick the analyte name from the list
Units	Pick the analysis units from the list
Sample Method	Pick the analysis method from the list
Preparation Method	Pick the preparation method from the list, if known
Result	Enter the result. If it is a non-detect, enter 0, and check (YES) the ND checkbox. Otherwise, enter the value. See note below.
Qualifier	Enter any data qualifiers identified by the laboratory
Method Reporting Limit	Enter the reporting limit if known. Required for non-detects.
ND Flag	Check (YES) if the result is a non-detect.

Note: Typically a laboratory will report a non-detect as 'less than a specified reporting limit' as the result. For example, if a result of '< 5 mg/l' is reported by the laboratory, where '<' indicates that the nothing was detected and '5 mg/l' is the reporting or detection limit tested against. To report non-detects in the database:

- *Enter a zero (0) in the* **RESULTS** *field.*
- *Check (***YES***) the* **ND CHECKBOX**
- *Enter the reporting limit in the* **METHOD REPORTING LIMIT** *field.*

This procedure must be followed in order for the reports to properly format non-detect results.

To view water quality results for a well, navigate to the well in the **DATA TREE**, expand the options for the well, and click on **WATER QUALITY**. Select the desired **COC** and **SAMPLE** from the pick list. The analytical results will be displayed in the grid below.

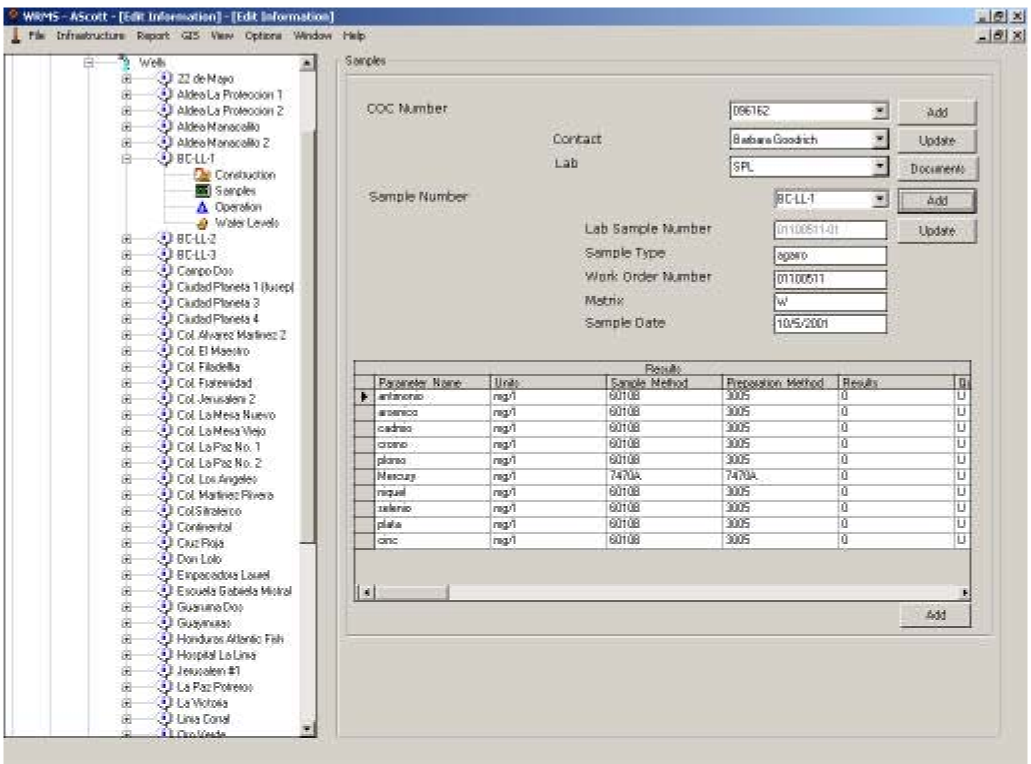

Figure 2-14. Analytical Results Table

To view an analytical summary for the well, go to the **REPORT** menu and select the **HITS REPORT**. See the Creating Reports section below for further details.

2.4.3.9 <u>Water Levels.</u> Water level measurements can be stored for each well by clicking on the **WATER LEVELS** option under the desired well in the **DATA TREE**. This will open a table of water levels for the well. To add one, click on the **ADD** button. A pop-up window will appear, prompting for entry of a new water level measurement. Enter the data and click on the **OK** button to save the entry. The following table shows the data elements associated with water levels.

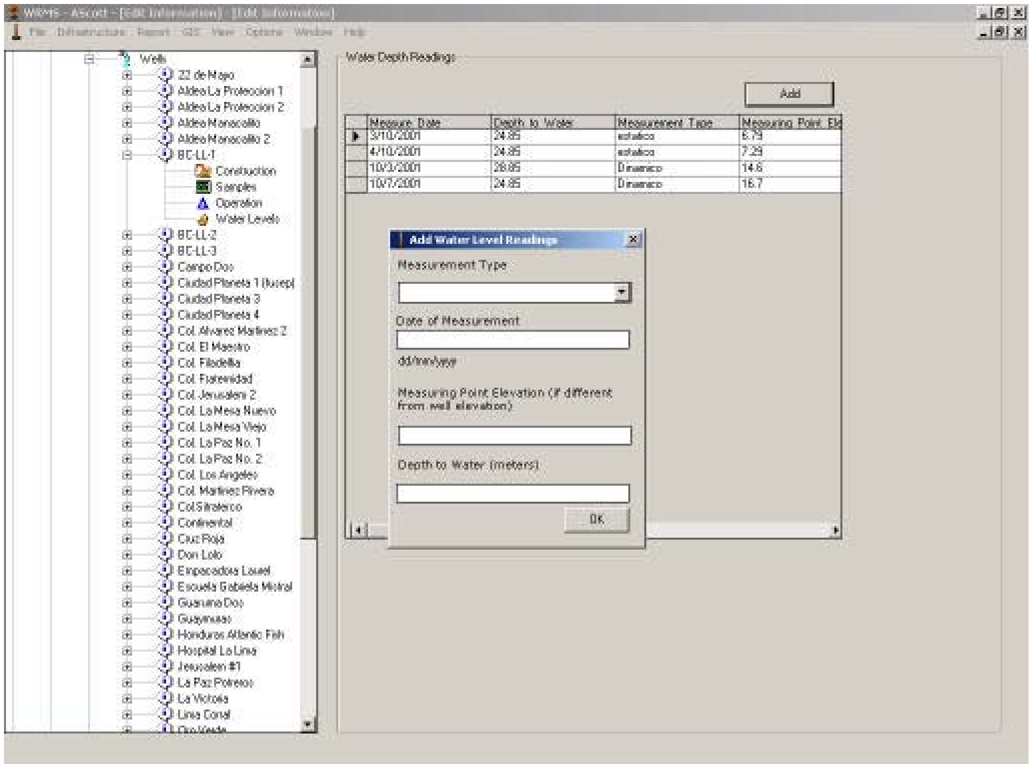

Figure 2-15. Water Level Measurement Data Entry Form

Data Field	Description
Measure Date	Enter the date the measurement was taken (DD/MM/YYYY)
Water Level	Enter the depth to water, in meters
Measurement Type	Pick the type of measurement (e.g. static or dynamic)
Measuring Point Elevation	Enter the elevation of the measuring point, in feet, if different from the well elevation. This is important in order to accurately identify the water table elevation at the well.

2.4.3.10 Storage Tanks. Storage tanks within a service area are also stored in the WRMS. To navigate to storage tanks, expand the **STORAGE TANKS** branch of a particular service area.

To enter a new storage tank, click on the **SERVICE AREA** and right-click the mouse. A popup menu will appear. Select **ENTER STORAGE TANK**. A blank storage tank form will appear, prompting for the name of the new storage tank. Enter the name and click **OK**. A new storage tank will be entered into the database.

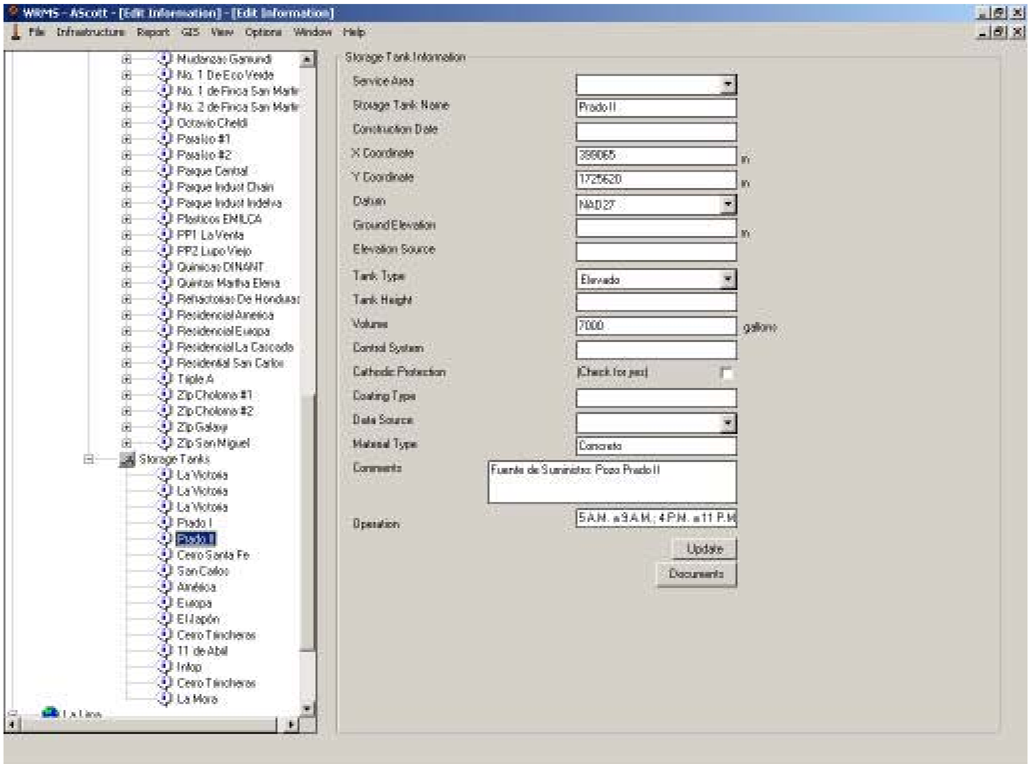

Figure 2-16. Storage Tank Data Entry Screen

The following table shows the data elements for storage tanks:

Data Field	Description
Service Area	Pick a service area from the list to change the designated service area
Storage Tank Name	Enter the name of the storage tank
Construction Date	Enter the construction date
Easting	Enter the Easting Coordinate in UTM meters., NAD27 Datum.
Northing	Enter the Northing Coordinate in UTM meters, NAD27 Datum.
Datum	Enter the Datum (e.g. NAD 27, WGS 84)
Elevation	Enter the elevation in meters
Elevation Source	Enter the source of elevation data (GPS, survey, map coordinates, etc)
Tank Type	Pick the type of tank from the list
Tank Height	Enter the height of the tank in meters
Volume	Enter the volume of the tank in gallons
Control System	Describe the Control System, if any
Cathodic Protection	Check (YES) if cathodic protection is available
Coating Type	Pick the type of coating from the list
Material Type	Pick the type of material from the list
Operation	Enter the hours of operation or enter continuous if operated 24 hours a day
Comments	Enter other descriptive information here

Data Field	Description
Data Source	Pick the source of the data. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.

Note: Coordinate must be entered in UTM meters using the NAD27 datum in order for the location to be properly placed on the GIS map. The user has the option of storing the coordinates using other datum, but these will not show up properly on the GIS map. It is important that these data be recorded accurately and correctly to avoid confusion about their physical location when display with other data.

2.4.4 Creating Reports. The WRMS allows the user to create standard reports from information in the database. These reports are tabular or graphical output that can be viewed on screen or printed to a standard printer.

The following reports are available:

- **HITS REPORT** – Lists all the positive analytical results for a selected well.
- **ANALYTE TREND** – Presents a linear graph showing concentration over time for a selected analyte for a well.
- **WELL CONSTRUCTION** – Print out well construction specifications for a set of wells.
- **WELL EQUIPMENT** – Lists equipment installed on selected wells.
- **WELL OPERATIONS** – Presents operational, maintenance, and cleaning information for wells.
- **STORAGE TANKS** – Lists storage tank specifications.
- **MUNICIPAL GROWTH** – Shows historical and projected growth and consumption information for municipalities.
- **SERVICE AREA STATISTICS** – Lists water consumption and use information for a service area.

Each report will be created using a similar process. To create a report:

1. Click on **REPORTS** on the main menu. The reports submenu will open up.
2. Click on the desired report from the submenu.
3. Once a report is selected, a series of popup windows will open prompting the user to make selections. For example, the **ANALYTE TREND REPORT** prompts the user to select one or more wells and then one or more analytes to display.
4. When selection is complete, the report will be generated for the wells identified.

2.4.5 Map Analysis. The WRMS can be used to create customized maps of water resource data. This is done using ESRI's ArcView® software. ArcView® is a geographic information system (GIS) used to view, analyze, and print customized maps and data.

ArcView® is integrated into the WRMS so that the user can launch a customized project from the WRMS user interface. This will open ArcView® showing all available GIS data for the municipality. The user will then turn on or off specific layers, change the map extent, interactively query the database for wells or storage tanks, and print out maps on a standard printer.

In order to the most flexibility and to leverage the existing capability of the ArcView® software, the standard ArcView® user interface has been used with minor enhancements. This users guide will present a brief overview of the inherent capabilities of ArcView®. For a detailed discussion using ArcView®, please see 'USING ARCVIEW GIS' users guide that comes with ArcView® or access the on-line help by clicking on **HELP; HELP TOPICS** from the menu bar.

The ArcView® system draws data from the WRMS database. For example, the coordinates for wells and storage tanks are derived directly from the database. Other information can be queried or viewed on the maps as well.

To open ArcView® from the WRMS, click on **GIS** from the main menu. A submenu will appear. Click on **BASE MAP**. This will open ArcView® and show all available data.

The figure below shows the main components of the ArcView® interface:

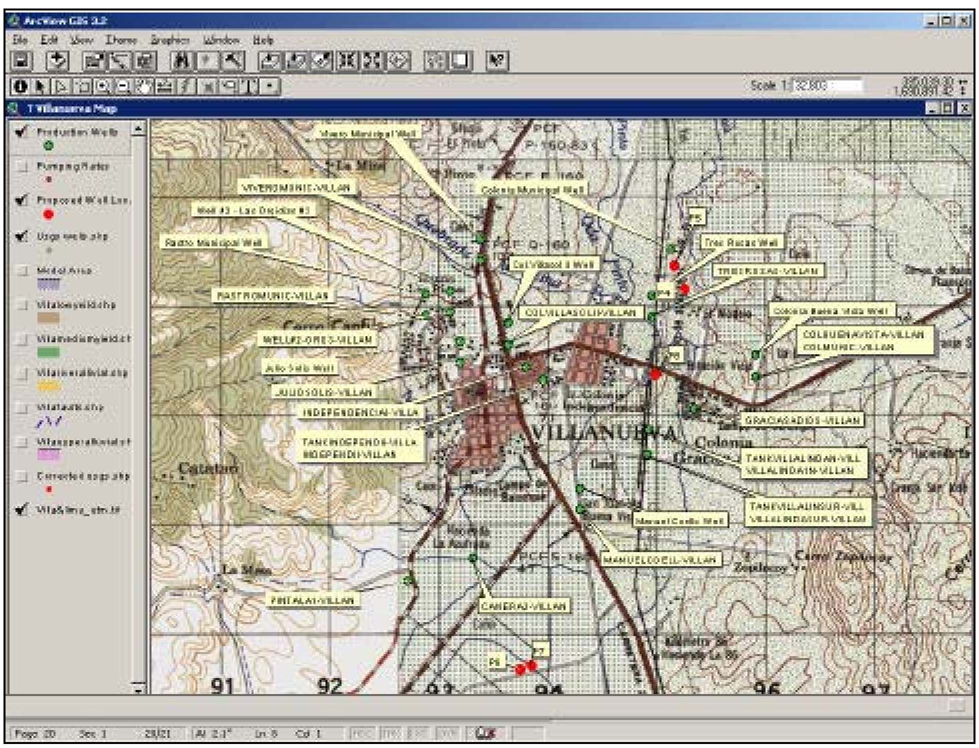

Figure 2-17. ArcView® Interface

The **MENU BAR**, **BUTTON BAR**, and **TOOL BAR** contain functions and controls for manipulating the map information, which is displayed in the map display area. The **LEGEND** is used to turn on and off data layers, and to change colors or symbols. The **MAP DISPLAY AREA** is where the map's elements are displayed.

Below, some of the most common ArcView® functionality is described, to enable the user to perform basic operations. Detailed description of ArcView® is beyond the scope of this document.

2.4.5.1 Close the ArcView® Interface. ArcView® is opened automatically when **BASE MAP** is selected from the **GIS** option on the WRMS main menu. This will open a separate ArcView® session every time the menu choice is selected. ArcView® and the WRMS window can both be open and operational simultaneously. To close the ArcView® session, select **FILE; EXIT** from the ArcView® Menu Bar. Alternatively, click on the 'X' in the upper right corner of the window. The user may be prompted to save changes before exiting. Saving changes will enable ArcView® to open to the same settings that were in place when the session was closed. Otherwise, ArcView® reverts to the previously saved settings.

2.4.5.2 Save Changes. The user can save changes made during the ArcView® session at any time. Either click on the **SAVE** button on the tool bar, or select **FILE; SAVE PROJECT** from the menu bar

2.4.5.3 Turn On or Off Layers. Each map layer that can be displayed is shown in the legend on the left side of the screen. Turn on each layer by clicking on the checkbox to check it. The map display area will be redrawn with the new layer shown. Uncheck the box to turn off the layer.

Each map layer (called a 'Theme' in ArcView®) corresponds to a source data file, called a Shapefile. Shapefiles each have an extension (file suffix) of 'shp' and are stored as regular files on the computer system. The shapefile contains the graphics and attribute data necessary to select and display information in the map display area. Please see the 'USING ARCVIEW GIS' users guide or access the on-line help (by clicking on **HELP; HELP TOPICS** from the menu bar) for more information on manipulating and adding shapefiles.

2.4.5.4 Change Symbol. The symbols for each of the map layers can also be changed. To do so, click on the layer so that it is highlighted by a box, then click on the **EDIT LEDGEND** button on the tool bar. This will open the legend editor pop-up window. Double click on the symbol (put the pointer on the symbol and click the left mouse button twice rapidly) to open the symbol window. Chose a new symbol, color, or line symbol and click the 'X' in the upper right hand corner of the symbol window. When the symbol window has closed, click on the **APPLY** button on the legend editor window to update the map with the new symbol. Close the legend editor window by clicking on the 'X' in the upper right hand corner.

2.4.5.5 Zoom In or Out. The geographical extent of the map view can be changed by zooming in or out. To zoom in (examine a smaller area in more detail), click on the **ZOOM IN** button on the tool bar. The cursor will change to a cross. Place the cursor on the new upper left-hand corner, press *and hold* the left mouse button. Drag down and to the right to define the new area for the map. When the button is released, the map will be redrawn to the new boundaries in the map display area. To return to the previous image, click on the **PREVIOUS EXTENT** button on the button bar.

To zoom out (see more area), click on the **ZOOM OUT** button on the tool bar. Place the pointer in the center of the map display area and click the mouse. The area will be enlarged by a power of two. Continue to zoom out until the appropriate display is shown.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.6 Pan. The user may want to move to a new area of the map without changing the scale of the display. This is called a pan. To pan, click on the **PAN** button on the tool bar . The pointer will turn into a hand.

Place the hand on the location on the map that will become the new center in the map display. Press *and hold* the left mouse button. Drag the location to the center of the display. The map will be dragged over to become the new center of the display.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.7 Identify Data. ArcView® allows the user to explore associated data for any of the data layers shown. To do so, click on the desired data layer in the **LEGEND** so that it is highlighted with a box. Then, click on the **IDENTIFY** button on the tool bar . The pointer will become an 'i' with cross-hairs. Put the pointer over the desired feature and click the mouse. A popup window will appear showing related data for the feature selected.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.8 Measure Length. To measure the distance between map features, click on the **MEASURE** button on the tool bar . The pointer will turn into a ruler. Click on a point to begin measurement. Click as many times as needed to define the line (the measurement does not have to be a straight line). The segment length and total length will be shown on the status bar on the bottom left-hand side of the screen. When finished double-click the last point.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.9 Print a Map. There are two ways to print a map. Either print the current view or create a layout for printing. Printing the current view is a quick way to produce a paper copy. Using a layout allows the user to produce a more formal map.

To print the current view, click on **FILE; PRINT** from the menu bar. A printer popup window will appear. Click **OK** to print

To create a default layout for printing, click on **VIEW; LAYOUT** from the menu bar. This will open the **LAYOUT MANAGER** popup window. Select the **LAYOUT TEMPLATE** and click **OK**. Select a new layout and click **OK**. A new layout will be created for printing. To print the layout, make sure the layout window is the active window (click on the layout once to make sure). Then print using the **FILE; PRINT** menu selection from the menu bar.

Close the layout by clicking the 'X' in the upper right-hand corner of the window.

For a detailed discussion on customizing layouts, please see 'USING ARCVIEW GIS' users guide that comes with ArcView® or access the on-line help by clicking on **HELP; HELP TOPICS** from the menu bar.

2.4.5.10 Well Classification. Well data can be displayed in the current view. The wells will be color coded by the type of data selected. The types of data that can be displayed for wells are:

- **TOTAL DEPTH** – Plots the wells by total well depth (in feet),
- **STATUS** – Plots the wells by their status (e.g. active, abandoned),
- **WELL TYPE** – Plots the wells by their construction type (e.g. bored, hand dug),
- **WATER LEVEL** – Plots the wells by their water level elevation,
- **WQ PARAMETER** – Plots the wells by the concentration of a selected analyte.

To plot well classifications, do the following:

1. Select **WELL ANALYSIS** from the menu bar. This will open a sub-menu.
2. Select **WELL CLASSIFICATION** from the submenu. A pop-up window will appear.
3. Select the desired well classification. Once selected, the well symbols will be color coded by the type of classification selected.
4. (For **WQ PARAMETER** only**)** An additional menu will appear listing the analytes that can be plotted. Select the desired analyte.
5. (For **WQ PARAMETER** only**)** Once an analyte is selected, a threshold value or reporting limit can be entered. Enter the limit or value and click ok. Wells with analytical data above the limit will be colored red.

2.4.6 Well Site Prioritization. The purpose of the well site prioritization tool is to identify and prioritize candidate locations for new wells based on a user-defined set of selection criteria. The typical process for evaluating well sites is to evaluate each site against a list of specified criteria. Each site gets a numerical score for each item in the list based on how well it meets the specification. The scores are then totaled for each site, and the site with the best score becomes the best candidate for new well facilities.

An example matrix of this prioritization approach is shown in the table below.

Criterion	Multiplier	Site 1		Site 2		Site 3		Site 4	
		Rank	Value	Rank	Value	Rank	Value	Rank	Value
Pumping Cost	1	2	2	2	2	2	2	1	1
Proximity to Existing Pipelines	1	3	3	3	3	2	2	2	2
Land Ownership	2	3	6	3	6	3	6	2	4
Groundwater Quality	3	4	12	4	12	4	12	3	9
Impacts on Existing Wells	4	1	4	1	4	1	4	0	0
Aquifer Characteristics	8	5	40	5	40	5	40	4	32
Aquifer Thickness	10	3	40	1	10	3	30	2	20
Total			**97**		**77**		**96**		**68**

The candidate sites are listed across the top of the matrix and the criteria to be scored are listed on the left. Each criterion is assigned a weighting factor shown in the multiplier column above. This multiplier enables the criterion that is most important to contribute the most to the final score, and thus have the most influence on the prioritization. Each site is assigned a rank, which is multiplied by the multiplier to get an overall value for each individual criterion. The values are then summarized to a final score for each site, which is used to determine the sites that best meet the criteria.

The well site prioritization tool performs this process on the entire region to be evaluated. Each criterion in the matrix table is represented by an ArcView® shapefile theme (Please see 'Turning on or off layers in the section above for a description of shapefiles[2]). In some cases, an item from the shapefile's attribute table will need to be identified. The tool will process each shapefile into a grid (Grids are discussed in the ArcView® 'USING SPATIAL ANALYST' users guide) is developed for the entire study area, and each cell in the grid is evaluated and scored against the criteria. The scores are then added together and the cells are categorized based on how well they meet the criterion. These categories are then displayed on the basemap. The areas with the highest total scores (green) are the best candidates for new well production, and the worst are shown in red.

2.4.6.1 Entering Criterion. The Well Site Prioritization Tool already contains an example set of pre-configured criteria for analysis and decision-making. The user may start with these and make changes to evaluate the study area. This section describes in detail the concepts and procedures involved in creating and manipulating new criteria. The last part of this section describes the user interface and how to change criterion parameters.

When entering criteria, there are three types of criteria evaluation methods used in the model. These are shown in the table below:

Table 2-8. Types of Analysis Methods Used in the Well Site Prioritization Tool

Method	Description	Example	Shapefile Type	Shapefile Item	Fields Used
Value	Areas that *EQUAL* a specific value are assigned a specific rank	Any area that falls within a municipal boundary.	Polygon	Any text item	Text Value

[2] Note: Adding and defining criteria in the Well Site Prioritization tool requires an understanding of ArcView® shapefile construction, which is beyond the scope of this manual. . For a detailed discussion, please see 'USING ARCVIEW GIS' users guide that comes with ArcView® or access the on-line help by clicking on HELP; HELP TOPICS from the menu bar.

Method	Description	Example	Shapefile Type	Shapefile Item	Fields Used
Range	If the value falls within a specific *RANGE*, it is assigned a specific rank	Aquifers greater than 150 feet thick are best; aquifers between 100 and 150 feet are good; anything less in unacceptable	Line	Any numeric item	Low Value and High Value
Buffer	Used to assign rankings based on *DISTANCE FROM* a map feature	New well sites should be within 500 meters of existing infrastructure	Line or Point	None required	Buffer, Text Value (optional)

The first step in defining criteria for the model is to complete a worksheet like the example shown below. Blank forms are located in the back of this manual. In the first column, list the criterion or theme name and the significance of the criterion by assigning a multiplier. Next, select the method to be used from the table above. Next, identify the shapefile to be used in the analysis (the type of shapefile is specified for each method in the table above). Identify an attribute item to be used in the evaluation, if required by the method. Then, identify the appropriate key word for the selected method from the description field in the table above (the *CAPITALIZED / ITALICIZED* words). Next, using as many lines as necessary, fill in the possible values and their corresponding rank. Remember, these values must be present with the exact spelling and case in the attribute field selected.

In the example, there are five criterion specified, but the user can enter as many sets of criteria required for the analysis. It is even permissible to enter multiple sets of criteria for the same type of information. For example, if there are multiple aquifers present, the user can enter a set of aquifer characteristics (e.g. specific capacity) and water quality parameters for each aquifer as separate criteria.

Table 2-9. Example Worksheet for Defining Criteria for Well Site Prioritization

Criterion/ Theme	Weight/ Multiplier	Method	Shape File Name	Item for evaluation	Key Words	Value	Rank
Municipal Boundary	9	Value	boundary.shp	ID	EQUALS		
						"IN"	10
Specific Capacity	7	Range	aquifer.shp	Value	RANGE		
						0 - 50	1
						50-100	5
						100-200	7
						200-10000	10
Infrastructure	4	Buffer	infrastructure.shp		DISTANCE FROM		
						< 500	10
						> 500	0
Water Quality	4	Value	quality.shp	Value	EQUALS		
						"EXCELLENT"	10
						"GOOD"	5
						"POOR"	0
Supply Wells	5	Range	wells.shp	Status	DISTANCE FROM		
						< 100	0
						> 100	10

Once the sheet has been completed and the multipliers and ranks have been satisfactorily assigned, the data can be input into the WRMS. To do so, click on **GIS** from the main menu and pick **WEIGHTED VALUES.** The data entry form shown below will open.

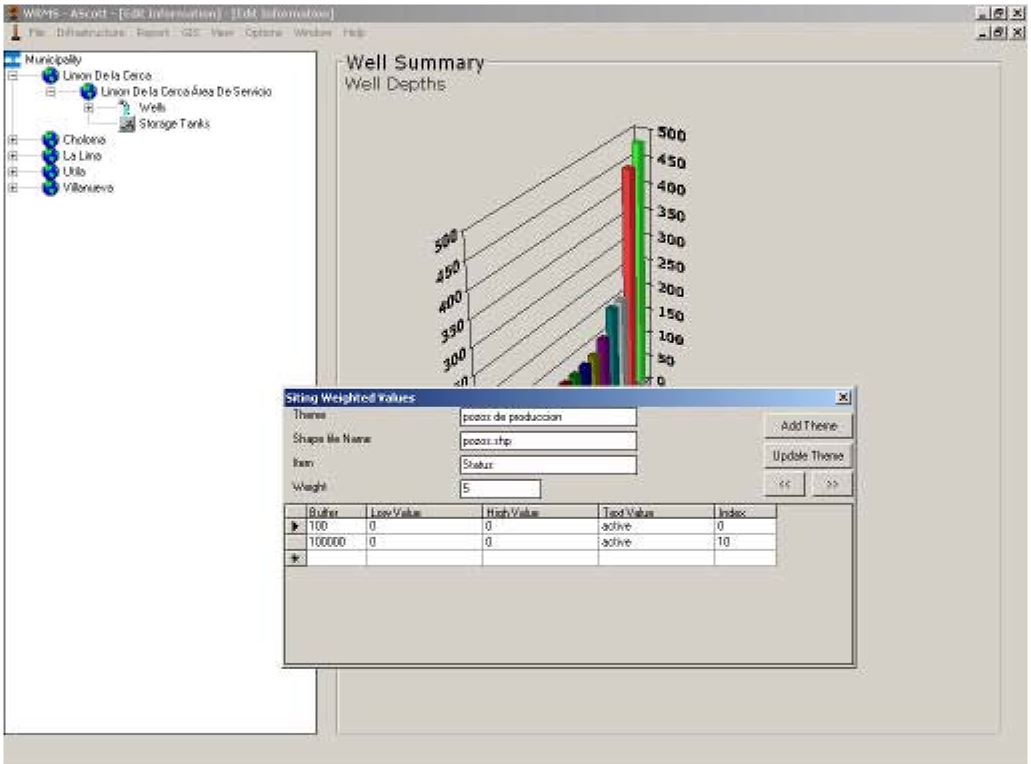

Figure 2-18. Well Siting Criterion Data Entry Screen

To enter a new criterion, do the following:

1. Click on the **ADD THEME** button. A pop-up window will appear.
2. Enter the theme name, shapefile name, field used (if any) and the weight value for the criterion.
3. Click on the **SAVE** button to store the new record.

To update a theme, enter the changes and click on the **UPDATE THEME** button.

To navigate between criteria records, click on the forward (>>) and back (<<) buttons.

1. To specify the parameters for the new criterion, click on the blank row and start entering data

Once the criteria are entered, use the same procedure to make updates and adjustments to the ranking and multiplier fields to calibrate or tune the model.

2.4.6.2 Performing the Analysis. Once the criteria are specified, the site prioritization process can be run. To start the process:

2. Click on **GIS** from the main menu and select **WELL SITE PRIORITIZATION**. An ArcView® GIS session will be initiated.
3. Select **WELL ANALYSIS** from the **MENU BAR**
4. The analysis will begin. When completed, a new layer will be added to the map display area with its corresponding scores in the legend. The values are color-coded, based on the colors shown in the legend. The higher the values, the better the match to the specified criteria.

Typical results are shown in the figure below

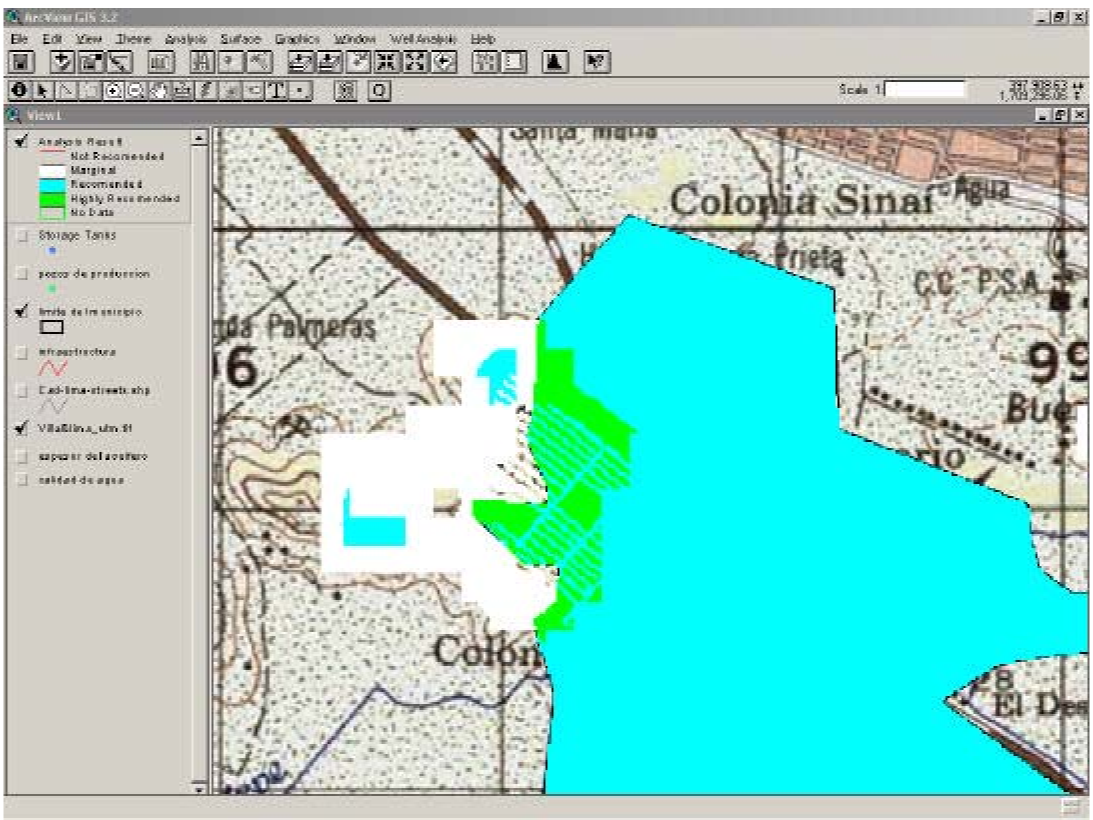

Figure 2-19. Well Site Prioritization Results

2.4.6.3 Querying the Results. The user may adjust the criteria and run the model as many times as necessary to identify reasonable ranking and multiplier values. In order to explore the results and identify the most significant contributing criteria for any location, a criteria query tool has been provided. To use the tool perform the following steps:

1. While in the ArcView® session, click on the criteria query tool button in the tool bar Q.

2. Locate the pointer over the location to be explored and click the mouse. A series of pop-up windows will appear displaying the criteria, the value, the weight, and total value for the point selected.

Typical results are shown in the figure below.

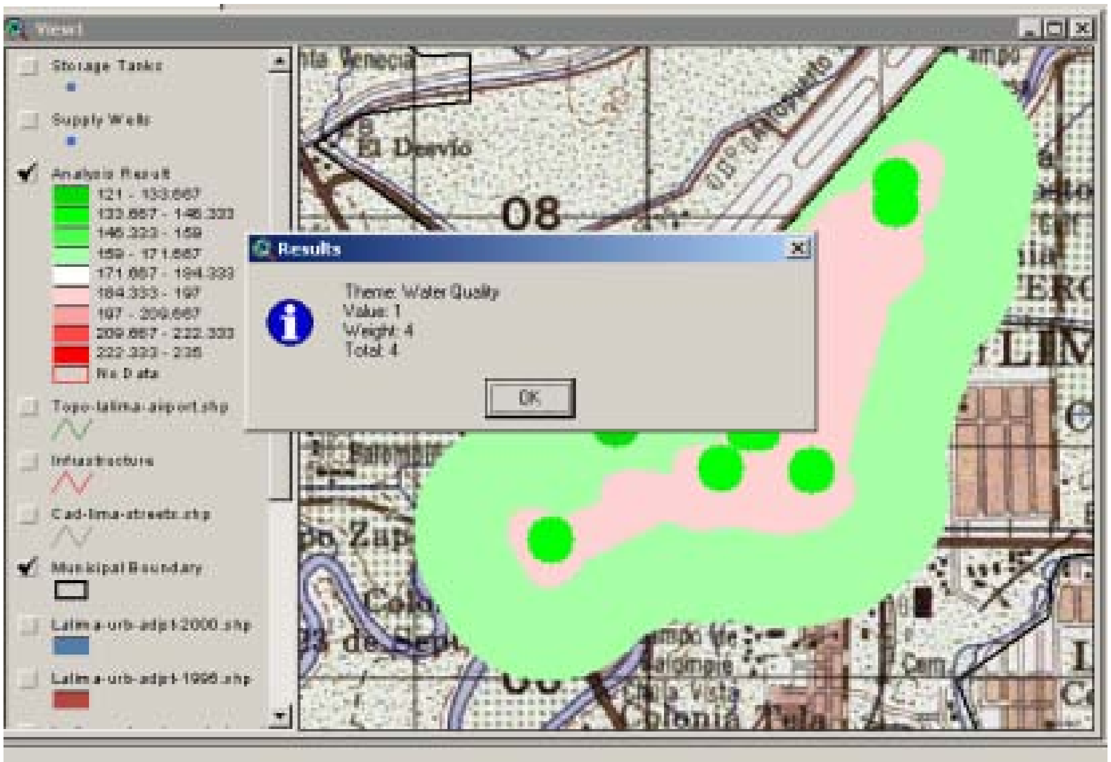

Figure 2-20. Using the Query Tool for Exploring the Siting Analysis

Using this tool, the user can evaluate the scoring characteristics for any location in the study area.

2.4.7 Assessing Related Information. The WRMS provides access to the GW Monitor – the USGS database of water supply wells – and the Water Resources Management Plan developed as part of this project. GW Monitor is an Access database that contains specifications on many of the water supply wells throughout Honduras. Many of the wells identified in WRMS are also present in GW Monitor, and it will be useful to compare the information between the two databases. To access GW Monitor, click on VIEW option from the WRMS main menu, then select USGS DATA. The GW Monitor application will open in a new window.

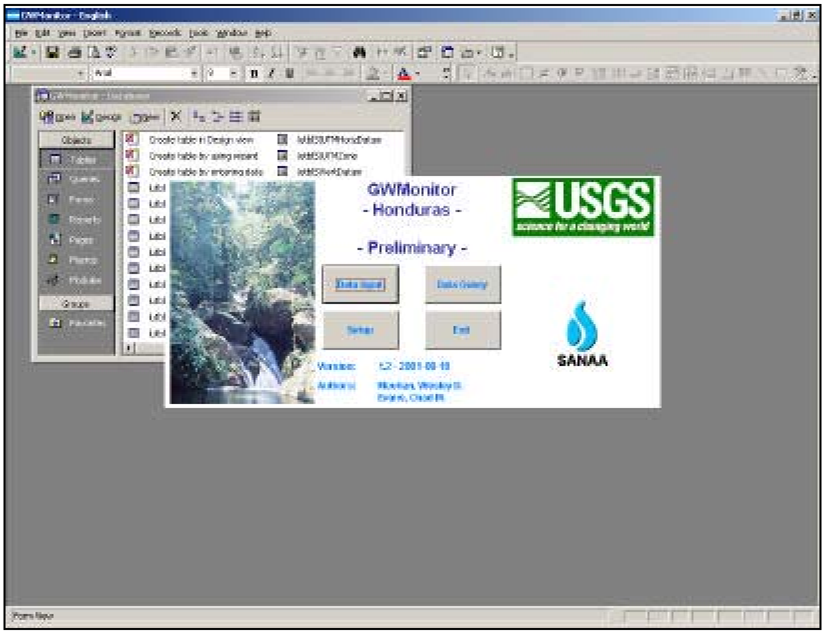

Figure 2-21. GW Monitor; the USGS Wells Database for Honduras

Once open, wells in the GW Monitor database can be queried through the functionality provided by the USGS. Please contact the USGS for information on how to use the GW Monitor database.

The Water Resources Management Plan is a report developed for each municipality containing a summary of water resource information, analysis of sustainable yield and aquifer characteristics, and recommendations for water resource management programs. The Water Resources Management Plan and WRMS are to be used in conjunction with each other. There are detailed data in the WRMS discussed and summarized in the plan, and recommendations from the plan can be explored using the WRMS. To access the Water Resources Management Plan, click on the **VIEW** button from the main menu, then select **WATER RESOURCES MANAGEMENT PLAN**. The plan will be opened in PDF format for viewing.

2.4.8 Getting Help

There are two type of user assistance available in the WRMS; assistance with the application and assistance with the ArcView® software.

2.4.8.1 WRMS Help. This users guide is available in PDF format from within the WRMS. To access help, click on **HELP** from the main menu, then select **USERS GUIDE**. The users guide will then open up in a new window. To access version information regarding the WRMS application, click on **HELP** from the main menu, then select **ABOUT**. This will open a popup screen showing the application version.

2.4.8.2 ArcView® Help. As mentioned previously, comprehensive discussions of ArcView® structure and functionality is available on-line from the ArcView® application. To access, click on **HELP** from the menu bar, then select **HELP TOPICS**. This will open a new window with help documentation.

3.0 ADMINISTRATORS GUIDE

3.1 Architecture

As mentioned previously, the data management system used in the WRMS is Microsoft Access, which is a relational database designed to efficiently manage complex data. The data are stored in a series of tables. Each table stores a different type of information, and each table is linked to others by a key field that defines the relationship. For example, one table contains a record of each well, while another table contains all the water level measurements. The table containing the water levels also contains the name of each well, so that it can be linked back to the appropriate well in the well table. This way, detailed information on each well and water level measurements can be stored most efficiently, without the need to maintain the same piece of information more than once, which would potentially introduce erroneous data into the system.

The GIS used is ArcView®, by Environmental Science Research Institute (ESRI). A GIS is an electronic mapping and analysis system. The power of GIS lies in its ability to manipulate, display, and analyze information on a map by linking map elements to attribute data in a database. For example, a well whose location is identified as a dot on the map, is connected to the construction data, sampling results, and water level information in the database. The user can post any of this information as text on the map, choose specific symbols or colors to represent these data, and overlay this layer of information on other map features. Because the data management system and GIS work together, it provides the user with a powerful set of management and analysis tools.

Both of these components are linked through a common interface developed in Microsoft Visual Basic. The interface is a series of screens that guide the user through various application functions. Through the interface the user can enter or update data, view reports, generate graphs, display scanned images, and create customized maps. The interface can be displayed in English or Spanish, uses water resource terminology, and is designed to be easy to use. Through this interface, municipalities will be able to continue to update their water resource data and use it for decision-making into the future.

3.2 Installation

The WRMS Application requires the following components to be fully installed on the system.

3.2.1 Hardware Requirements:

Minimum (Untested) configuration:

- Intel Pentium 200 MHz
- 64Mb RAM
- EIDE Drive (at least 100Mb free).

Recommended (Tested) configuration:

- Intel Pentium III 733+ MHz
- 128+Mb RAM
- EIDE RAM (at least 100Mb free)

3.2.2 Software Requirements:

The WRMS is designed to function on Microsoft Windows ME, NT4, 2000 or XP.

Additional Required Software:

- ESRI ArcView® 3.1
- ESRI Spatial Analyst
- Seagate Crystal Reports for ESRI
- Adobe Acrobat Reader (http://www.adobe.com/products/acrobat/)

3.3 Operations

This section explains how to back-up and restore the WRMS data and what to do if a system error occurs.

3.3.1 Backups and Recovery. WRMS features a basic backup and recovery system. The system allows the data stored in the system to be backed up whenever necessary. It is recommended that you set this system to backup your data at least once a week. This will enable you to recover your data if something goes wrong.

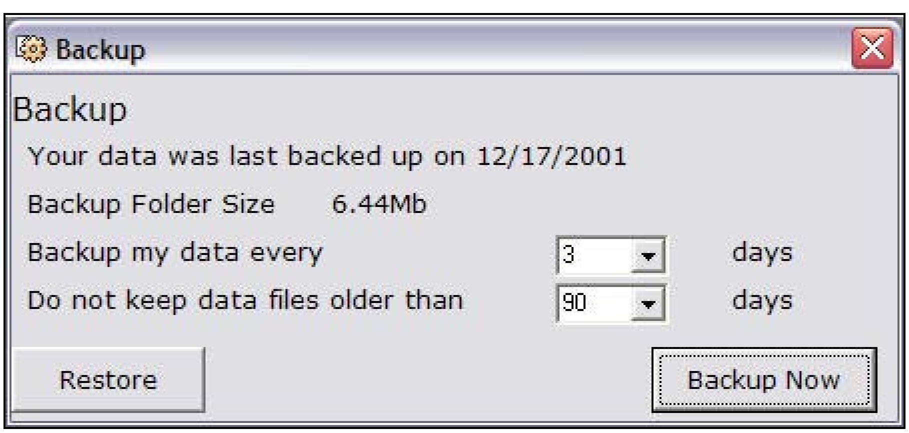

Figure 3-1. Backup and Restore Information

3.3.1.1 How to Backup Your Data. Backups are automated so there is no need to manually backup anything.

However, if you are planning on making major changes to your data or would just like to force a backup, you can force the backup by clicking the **BACKUP NOW** button.

3.3.1.2 How to Restore Your Data.

Click the **RESTORE** button on the **BACKUP** screen.

Figure 3-2. Restore Warning

Read the warning and make sure you understand the consequences of restoring OLD data.

Press **YES**.

You will then be presented by the following screen.

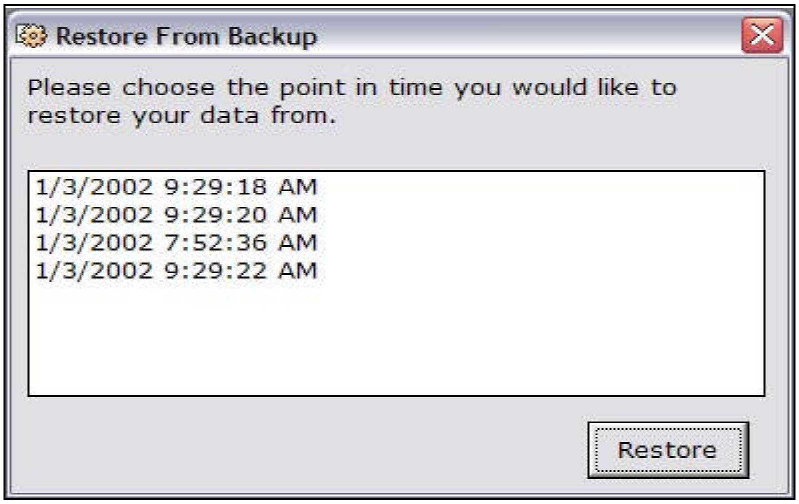

Figure 3-3. Restore from Selection of Backups

Select one of the items from the backup list. Then click **RESTORE**.

Your data will be backed up and then restored from the old data. It is recommended that you exit the application before using it again.

3.3.2 What to do if Error Occurs. We do not anticipate you encountering any errors. However, if you do encounter any errors make sure you write down the error number and what you were trying to do at the time that the error occurred. Send the details to the following email address: sac-support@brwncald.com.

3.3.3 Options

This section describes how to manage valid values, data paths, and interface translations.

3.3.3.1 Valid Values. Valid values allow you to alter and add to the contents of the drop-down menus. The illustration below shows part of the WRMS application. It includes a drop-down menu to change the well purpose of a well. The menu is populated using valid values.

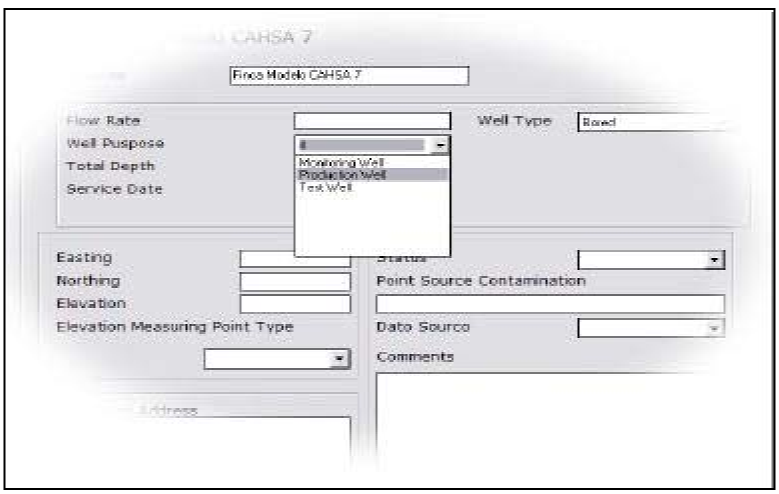

Figure 3-4. Well Purpose Drop-Down Menu Populated with Valid Values

You can easily change the valid values for this drop-down menu by pointing to **OPTIONS; VALID VALUES** then clicking on **WELL PURPOSE**.

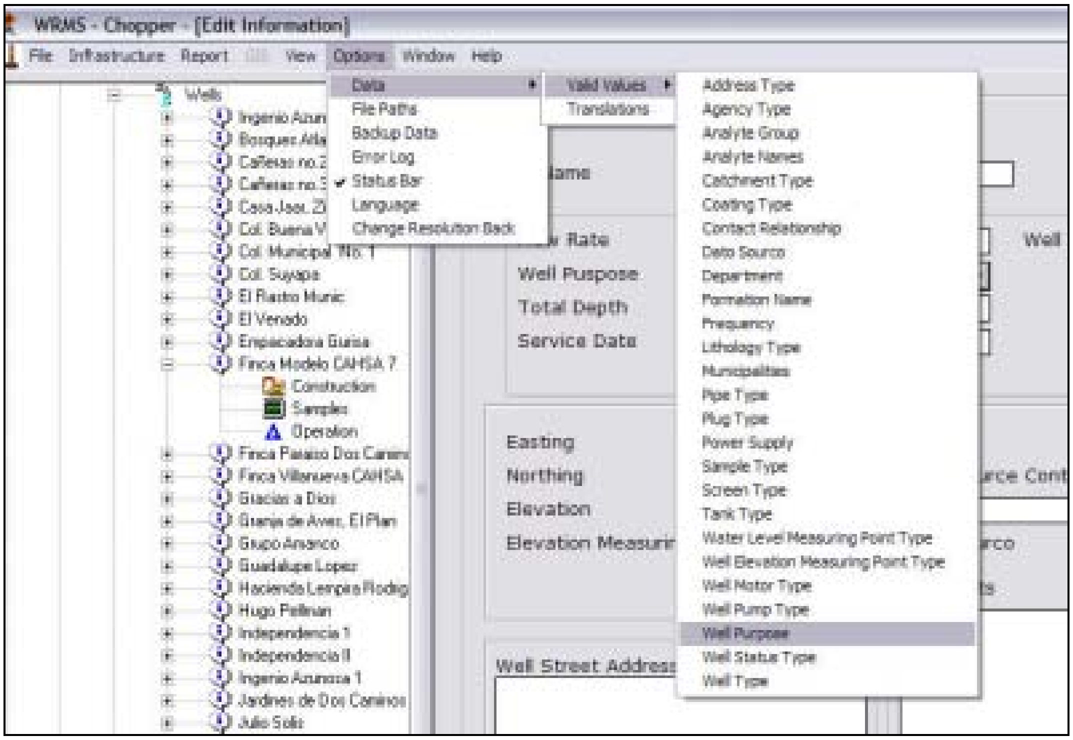

Figure 3-5. Valid Values Menu

You should follow the same process for any other drop-down menu in the application. This way the values can be easily managed.

3.3.3.2 Data Paths. WRMS requires some additional files to run with the full functionality. The following files should be setup in the **FILE PATHS** menu under **OPTIONS**.

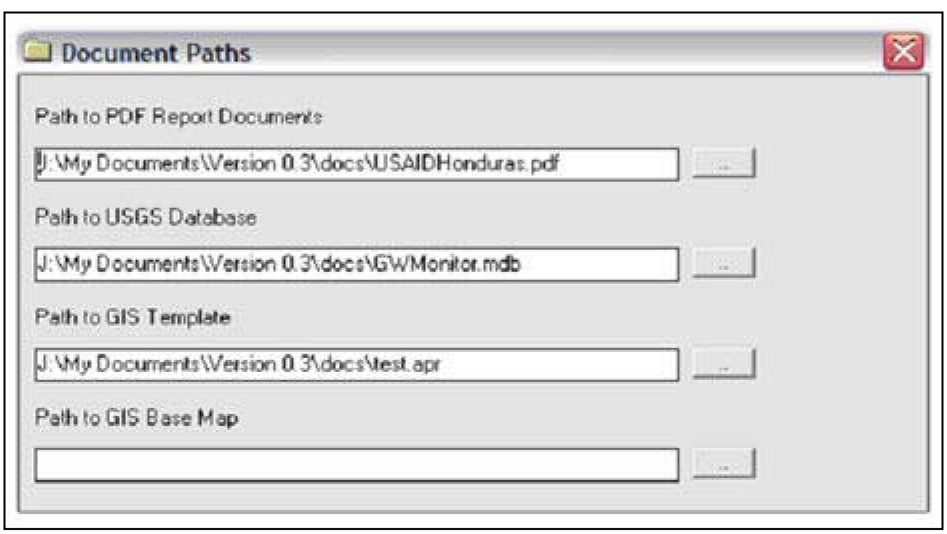

Figure 3-6. File Paths

Unless you are sure what you are doing, we strongly suggest you stay away from these options.

3.3.3.3 Translations. WRMS supports both English & Spanish. Because WRMS was developed in English, some of the translations may be incorrect. You may change these at any time by pointing to **OPTIONS; DATA** and then clicking on **TRANSLATIONS**. Here you will be presented with the English version of all the phrases that the application uses. You can update the Spanish by typing in the cell to the right of the English.

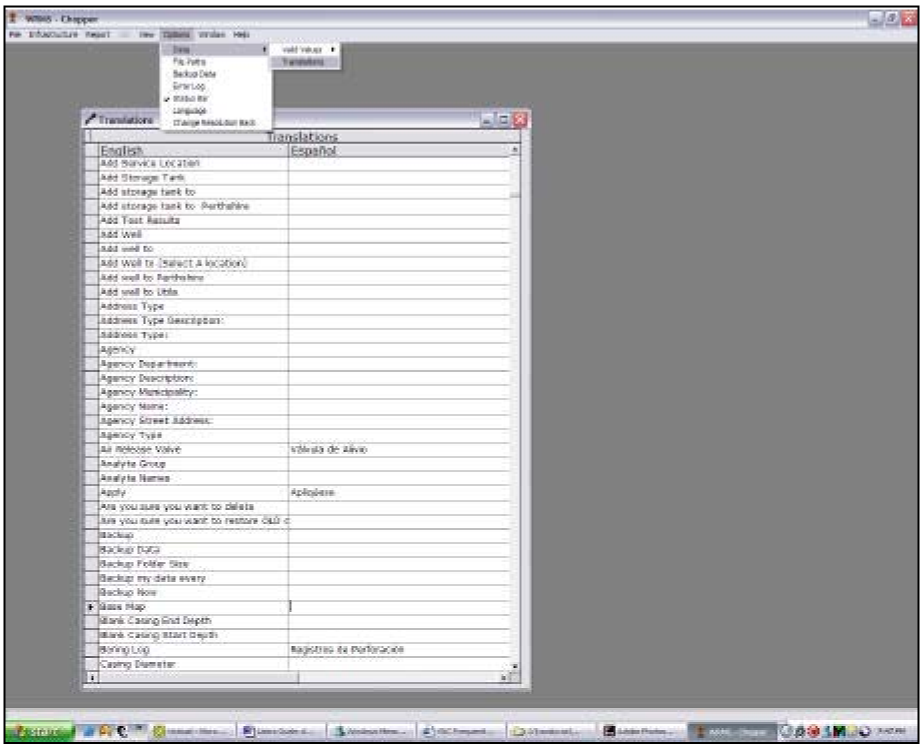

Figure 3-7. Translations Screen

ATTACHMENT

Criteria Worksheet

CRITERIA WORKSHEET

Criterion/Theme	Weight/ Multiplier	Method	Shape File Name	Item for Evaluation	Key Words	Value	Rank

Key Words: Equals
Range
Distance From

APPENDIX E

Groundwater Level and Monitoring Program – Field Manual

GROUNDWATER LEVEL AND MONITORING PROGRAM

FIELD MANUAL

BROWN AND CALDWELL

DECEMBER 2001

USAID

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APPENDICES

1.0 PURPOSE AND OBJECTIVES

The purpose of this Sampling and Analysis Plan (SAP) is to outline the essential elements for establishing an effective groundwater level and monitoring program at various municipalities in Honduras, Central America. This report and guidance document is written in support of the Groundwater Monitoring Study conducted by Brown and Caldwell under USAID contract number 522-C-00-01-00287-00. This report covers the technical approach for the groundwater level and monitoring program, the rational for established procedures and step-by-step guidance for the continuation of the monitoring program into the future.

2.0 OVERVIEW

The groundwater level and monitoring program is being established to provide a tool that will be used in support of the current groundwater modeling effort. In addition, the monitoring program will provide a tool for future data collection that will be useful for growth planning.

The groundwater level and monitoring program has several components that are all equally important. These components include groundwater level data collection, water sample collection, analysis of water samples and review, compilation and understanding of water chemistry results. Each of these components is necessary in order to maintain a successful groundwater monitoring program. Each of these components is used to support and enhance the groundwater modeling effort and is discussed in more detail in later sections of this report.

3.0 TECHNICAL APPROACH

3.1 Well Selection

For this study, two types of wells were selected for monitoring: existing municipal or private wells, and new test and observation wells recently installed by Brown and Caldwell. All of the newly test and observation wells will be sampled for this study. Only a selected group of existing municipal and private wells were selected from each municipality for use in this monitoring program. The rational for choosing the existing wells included the following criteria:

- Geographic location—no more than one well per square kilometer was chosen to provide enhanced spatial distribution over the study areas.
- Proximity to Contamination—priority was given to wells located in areas that are assumed to be beyond the extent of agricultural or industrial contamination.
- Depth of the Screen—priority was given to wells screened in deeper aquifers with less chance of contamination from outside sources.
- Daily Use of Well—a representative number of wells that are heavily used and wells that are not pumped often were selected for the monitoring program.
- Use of Water—a representative number of wells used for residential, industrial and agricultural purposes were selected for this monitoring program.

In total, it is proposed to monitor and sample 52 wells for the survey. These wells consist of:

- 14 wells in Villanueva (nine existing wells and five newly installed wells)
- 17 wells in Choloma (14 existing wells and three newly installed wells)
- 12 wells in La Lima (nine existing wells and three newly installed wells), and
- 9 wells in Limon de la Cerca (six existing wells and three newly installed wells)

These wells are listed individually in Tables 1 through 4, and located on the figures in Chapter 3 of the report. It is important to note that the same wells will be sampled during each monitoring event to provide consistency in data and allow for ease of tracking trends in data over time.

3.2 General Groundwater Level and Sampling Procedures

The groundwater level and monitoring program has several components that are essential to support and enhance the groundwater modeling effort as well as provide a base of historical data that can be tracked over time. These components include groundwater level data collection, water sample collection, analysis of water samples, and review, compilation and understanding of water chemistry results. Each of these components is descried separately below.

3.2.1 Groundwater Level Data Collection. Groundwater levels will be measured so that changes in groundwater elevations can be documented and analyzed over time. For example, analysis of groundwater elevations over time can reveal seasonal trends. To collect groundwater levels, field personnel lower an electronic water level indicator down the well until groundwater is encountered (indicated by a beeping noise from the equipment). This depth to groundwater is then recorded in the log book. The water level measurement will be converted into an elevation by subtracting the depth to water from the well surface elevation. A more detailed description of the procedure for collecting groundwater level data is provided later in this text.

3.2.2 Groundwater Sampling. Following collection of the groundwater level measurement, a water sample will be collected. At a minimum, all wells included in this program will be sampled and analyzed for general chemical parameters, pH, electrical conductivity, bateriology and heavy metals. All wells in the monitoring program will also be analyzed for gross alpha and gross beta to establish the presence or absence of radiological compounds. Any of these minimum analytical parameters that are not detected in large quantities in the initial sampling event will be considered for elimination from future monitoring events.

In addition to analyzing for the minimum parameters described above, other important water quality parameters, including pesticides/herbicides and volatile organic compounds (VOCs), should be considered on a well-by-well basis. Sampling and analysis for these parameters will be based on information such as local land use and proximity to industrial activities. For example, the Caneras well fields in Villanueva will likely be sampled and analyzed for the presence of pesticides and herbicides because they are located within a sugar cane plantation. In Choloma, Well Colonial Canada is located near industrial runoff sources, and will likely be sampled and analyzed for VOCs.

Tables 2 through 5 provide a list of suggested monitoring parameters for each well included in this monitoring program.

3.2.3 Groundwater Chemical Analysis. After collecting groundwater samples from each well, the samples will be transported to the laboratory for analysis. For the initial sampling, conducted by Brown and Caldwell, some of the samples will be shipped to Southern Petroleum Laboratory in Houston, Texas, United States of America and some will remain locally in Honduras at Jordanlab located in San Pedro Sula.

3.2.4 Laboratory Data Review and Compilation. When the laboratory has completed the analysis of the samples, the data must be reviewed and compiled. For the initial sampling conducted by Brown and Caldwell, a chemist in the Sacramento, California office will evaluate the data and the data will be input into a project database. For subsequent sampling efforts, each municipality must assess the analytical data separately — look for trends with historical data, be aware of constituents that exceed health based guidelines, and perform quality assurance measures to verify the accuracy of the laboratory data. Once the data have been reviewed for accuracy and consistency, the data should be input into the database provided by Brown and Caldwell and the original copies from the laboratory filed for future reference.

3.3 Quality Assurance/Quality Control

Specific Quality Assurance/Quality Control (QA/QC) steps will be taken in the field and by the laboratory in order to document and ensure that the analytical data have the maximum amount of integrity. The QA/QC program for the groundwater monitoring will include collecting Quality Control samples, use of qualified laboratories, a specific laboratory reporting format, review of laboratory data packages, and consistency in sample identification. These QA/QC items are reviewed below:

- Samples will be carefully labeled with sample designation, the initials of the sampler, and the analysis to be performed. Date and time of sample collection will be added s the sample is collected.
- Field personnel involved in sample collection will wear disposable gloved to prevent potential contamination of samples. Gloves will be discarded after sampling each well.
- Groundwater samples collected from wells with dedicated pump systems will be collected with minimal potential agitation of the sample between the adductor pipe outlet and sample containers. All samples should be collected as closely as possible to the well head.
- Sampling heads should be constructed of non-metallic material, preferably polyethylene or Teflon®. Before collection of samples at all stations, the sampling heads will be cleaned in a non-phosphatic detergent and rinsed with tap water. This will be followed with a distilled-deionized water rinse.
- Groundwater samples collected from monitoring wells without dedicated pump systems will be collected with disposable Teflon or polyethylene bailers and nylon cord. The bailer and cord will be disposed of after the sample has been collected.
- Sample bottle guides for all parameters (bottle type, volume of sample needed, and type of preservatives used) are given in Table 3.

- Samples collected for dissolved metals will be filtered and preserved in the field.
- Immediately after collection of the sample is completed, the sample will be placed in a cooler at 4 degrees C.
- All pertinent information generated during the groundwater sampling event will be recorded on the Field Data Form and in the field log book.
- Duplicate samples will be collected as needed and are intended to be identical to the original sample. A field duplicate sample will originate from the project site and be in a separate sample container. Duplicates will be taken for approximately every 10 percent of samples collected during the sampling event, or a minimum of one per municipality per monitoring event. The location for duplicate sample collection will be determined prior to the sampling round.
- Equipment blanks will not be required because samples will be collected using dedicated pumps and disposable filters and bailers.
- Trip blanks will be provided by the laboratory whenever analysis of volatile compounds occurs.

3.3.1 Quality Control Samples. During each monitoring event, one blind duplicate sample will be collected from each municipality. A blind duplicate sample is a second sample collected from a predetermined well that is given a new (false) name so the laboratory does not know which well the sample is from. This method is commonly used to verify the accuracy of laboratory reports. In addition, a trip blank will be included in every cooler that is used to transport samples to be analyzed for VOCs. It is strongly recommended that this practice continue for all subsequent sampling events completed by the municipalities. A list of the wells that have been selected for duplicate sampling is illustrated in Tables 5 through 8.

3.3.2 Laboratory Qualifications. All chemical analyses will be performed by a laboratory certified by the USEPA or the Government of Honduras. Analytical methods and SOPs that are acceptable, in accordance with EPA recommendations, will be consistently maintained by the laboratory to satisfy the required QA/AC protocol.

3.3.3 Laboratory Data Packages. All results from USAID groundwater samples will be reported in modified Level 3+ QC data packages that provide the following documentation: sample chain-of-custody, method blank results, matrix spike/spike duplicate summary results, and detection limits listed on all reports. Data packages including all surrogate recoveries, laboratory control samples, initial and continuing calibrations, run logs, extraction logs, and correction action reports will be obtained from the laboratories as needed for individual samples.

3.3.4 Sample Naming Convention. For this groundwater level and monitoring program, the naming system will consist of three components: well name, month of the sampling event, year of the sampling event. For example, for the well named Cañeras 2 in Villanueva that will be sampled in October 2001 the sample name will be Cañeras 2 102001. It is important to follow this naming protocol so all samples have a unique identifier when they are entered into the database.

3.4 Schedule

The initial round of monitoring and sampling is scheduled for late October 2001. Sampling activities will be completed for one municipality prior to beginning sampling at the next municipality. This practice will be maintained in future monitoring events to reduce data analysis issues that may arise from weekly, monthly and seasonal changes in the water system. For the initial round of sampling, field work is anticipated to begin in Choloma and then move to Villanueva and La Lima. Finally, the samples will be collected in Limon de la Cerca.

4.0 DETAILED PROCEDURES

The following narrative provides a step-by-step outline of the activities necessary to complete the groundwater level and monitoring program. These steps should be followed each time groundwater samples are collected to ensure accuracy, consistency, and representativeness of data collected during this program.

4.1 Sampling Team and Responsibilities

The sampling team will consist of both field and office personnel. Each person on the team will have specific duties and responsibilities as described below.

- **Sampling Coordinator.** The sampling coordinator will have the overall responsibility for the sampling program and will be responsible for timing and scheduling of the sampling events, oversight of the sampling crew, and liaison with the laboratories. In order to respond to the changing requirements of the project, the sampling coordinator may, after consultation with the project manager, adjust the number and locations of samples to be collected, and the analytes for each sample.
- **Field Sampling Crew.** The field crew may consist of either two or three persons depending on the number of samples to be collected, and the time span allowed for that sampling. The field sampling crew will report directly to the sampling coordinator, and will be responsible for the physical collection of the samples according to the protocol described in this SAP.
- **Quality Assurance (QA) Reviewer.** This person will perform a detailed review of all data generated by this sampling program. The person will chart and document the water quality and will compare the analytical results to acceptable standards as they are available. After the results of each sampling event are reviewed, they will be compiled and a short data report will be prepared for each municipality for use by the project manager to document the results, any deviations from standards, and trends that may occur.

To ensure valid water chemistry determinations, the procedures outlined herein are based on guidelines established by the United States Environmental Protection Agency (USEPA, 1986) in the Code of Federal Regulations (40 CFR 100-149) and the U.S. Geological Survey (USGS, 1984).

4.2 Water Level Measurements

The following steps will be used to obtain water level measurements:

- On arrival at the wellhead, condition of the surface seal and protector or well cover will be checked and observations will be recorded in the field book.
- The area around the well will be cleared prior to unlocking the protector or well cover and removing the cap from the top of the well.
- Before taking any measurements, any previous data of water levels for the well will be reviewed.
- Measuring points will be established based on historical information. If no information is available, a notch on the north side of the well casing or the top of the sounding tube will be used.
- Each well will be sounded three times for depth to water with an electronic water sounder. Water level measurements will be continued until a difference of less than 0.02 feet between consecutive measurement is obtained.
- Depth to water and date of measurement will be recorded on the Field Data Form.
- The previous measured water level will be reviewed. If the difference between the current water level and historical water level measurement is greater than 1 foot, the current measurement will be rechecked.

Smoking, eating, or drinking in the vicinity of the well head, pump output, or field analytical setups will be forbidden in order to eliminate the potential for induced contamination.

Water level data will be collected and documented on the field sheet provided as Appendix A to this sampling manual.

4.3 Well Purging

Well purging activities include the following items:

- A minimal volume of water will be purged, taking into consideration the local hydrologic factors together with the stabilization of pH, temperature, and electrical conductance (EC) over at least two to three borehole volumes. The wells are expected to have very low-flow rates. Purging will possibly draw the water level down to a point that the pump will shut off due to lack of water. When this occurs, the well will be allowed to recover 80 percent of the original static water level, or for 24 hours. Sampling will proceed when these recovery conditions have been met.
- Readings of pH, temperature, and EC, will be recorded, and the cumulative volume pumped will be measured and recorded.
- Purge water will not be containerized but will be discharged directly to the surrounding ground surface.

4.4 Field Tests

During groundwater and surface water sampling activities, the following field tests will be conducted:

- Measurement of pH, temperature, EC, and depth to water in the well to be sampled will be taken and recorded immediately before and after collection of each groundwater sample.
- Conductivity, pH, and temperature meter probes will be thoroughly rinsed with distilled water prior to each use.
- The pH meter will be calibrated in pH 4 and pH 10 buffer solutions at the beginning and end of each sampling day. Calibration data will be recorded on the Field Data Form and in the field log book.
- The conductivity meter will be calibrated using manufacturer specified solutions before and after the sampling. Calibration data will be recorded on the Field Data Form and in the field log book.
- All field parameters will be collected and documented on the field data sheet provided as Appendix A to this sampling manual.

4.5 Groundwater Sample Collection

In order to ensure that proper groundwater samples are collected, the following items are required:

- The laboratory will be contacted at least two working days before receipt of the samples to establish a schedule for sample analysis. The following information will be provided for the laboratory:
  --approximate number of samples the laboratory will be receiving;
  --parameters to be tested;
  --holding time; and
  --number and types of sample bottles to be provided to the laboratory.
- All sample containers obtained from the laboratory shall be factory new. The exception to this is the jars received from JordanLabs in San Pedro Sula, Honduras for fecal and total coliform. These jars will be sterilized by way of an autoclave.
- An adequate number of forms will be obtained for documentation of field activities.
- Groundwater sample collection will be scheduled and performed to accommodate the required laboratory holding times, and to ensure that a maximum representation of the aquifer condition.

4.6 Sample Containers and Preservatives

Sample containers and appropriate sample preservatives will be provided by the laboratories performing analytical services. All container preparation by the laboratory will be done in a designated area. Containers will be labeled to indicate the added preservative. A full list of sample containers and preservatives for this project can be reviewed in Tables 2 through 5. Preparation is accomplished using the following SOPs for bottle preservation:

- Bottles for organic analyses will be provided by the laboratory. These will be purchased from suppliers who certify the containers to have been cleaned by protocols as prescribed in the Environmental Protection Agency (EPA) methods for organic analyses.
- Coolers, and applicable chain-of-custody forms will also be provided by the laboratories. Brown and Caldwell will be responsible for the purchase of bulk block ice that is appropriate for overseas shipping. Blue ice will not be used for cooling samples on this project.
- All sample containers with appropriate preservatives and coolers will be delivered at lease one week prior to sample collection.
- After a sample is collected, preserved, and labeled, it will be stored on ice at 4 degrees C in a plastic ice chest. No ice chest will be allowed to stay in the field beyond its ability to keep the temperature at 4 degrees C.
- All samples will be wrapped in plastic packing when necessary to avoid breakage, and will be clearly labeled and sealed to prevent tampering.
- All samples will have a label containing (at a minimum) the following information:
  --Sample designation;
  --Project name and number;
  --Date and time of collection; and
  --Comments – These may include parameters to be analyzed, whether the sample is filtered or unfiltered water, and any preservatives added to the sample.

4.7 Chain-of-Custody

Chain-of-Custody procedures will include:

- Samples collected by field personnel will be accompanied by a Chain-of-Custody Record Form, which will include date and time of collection, container type, preservatives used, number of samples, sample descriptions, and others.
- Sample identification labels and chain-of-custody records will be completed with waterproof ink, and placed in a waterproof bag for shipment.
- Chain-of-Custody documentation will be completed at each sample location prior to sampling at the next well.
- Samples will be hand delivered to JordanLabs in San Pedro Sula the day of the sampling. Samples that are being analyzed by Southern Petroleum Laboratory (SPL) in Houston, Texas will be delivered via DHL overnight shipment service. It should be noted that coliform samples have a short holding time of only 24 hours. It is imperative that field crew communicate with JordanLabs prior to sampling to verify that the analysis can be run in the appropriate time frame.
- The integrity of the samples will be examined, and the final signature of the Chain-of-Custody form will be completed by a receiving agent of the selected laboratory.
- A sample chain-of-custody is provided as Appendix B to this sampling manual.

5.0 DATA MANAGEMENT

Field and laboratory data management, data review, and reduction are given below to create a centralized working system, and to maintain data quality.

- Field Data. Water quality records for each sampling location will be produced, copied, and filed under the appropriate category for each groundwater quality well. Records completed in the field will include physio-chemical (pH, temperature, EC) parameters of groundwater and chain-of-custody records. These forms will be forwarded by the field manager to the project manager at the conclusion of the sampling effort.
- The following field documentation will be completed by the field personnel:
  --Complete entry in dedicated field notebook;
  --Complete the Field Data Form, and one Chain-Of-Custody Form.
- Laboratory Data. Analytical results and QC data relating to analytical precision and accuracy will be obtained from the laboratory. Laboratory analytical result data sheets will be specific to sampling location and method of analysis. The original Chain-Of-Custody Forms will be filed with the analytical results. Data will be organized with respect to date, original water quality results, and QA/QC results.
- Data Review. Field data will be reviewed for measurements collected during sampling, order of sample collection , and the observations and notes recorded during he course of the sampling day. Laboratory data forms will be reviewed for the completion of required measurements, including parameter results, limits of detection, and dilution factor. Validity of both the field and laboratory data will be determined by evaluating the completeness of the data for the required parameters as documented on the chain-of-custody form.
- The following data will also be reviewed:
  --Use of EPA methods with detection limits below water standards, where applicable;
  --Chemical data of control matrix blanks, control matrix spikes, standards, control matrix duplicates; and
  --Confirmation of sample analyses within specific holding times.

6.0 REPORTING

A general assessment of the groundwater and surface water quality for the fall of 2001 will be submitted to USAID in the final report presented at the termination of the project. It will be the responsibility of each municipality to report the water quality results to the appropriate individuals after each sampling event in the future.

7.0 GLOSSARY OF TERMS

Aquifer: The geological stratum that can produce enough water to support consumption. It is the section of the well where screening in a well is installed.

Bailer: a PVC tube one meter long used to collect water samples from wells that do not have a pump installed.

Casing: PVC or steel tubing installed into a borehole with perforated sections and non-perforated sections used to capture the water from an aquifer.

Chain-of-Custody: a legal document used to track groundwater samples. A chain-of-custody includes information such as the name of the sample, the date of collection, the time of collection, the name of the technician and the analysis requested by the laboratory. A chain-of-custody should remain with the samples at all times.

Database: A computer system used to archive historical data.

Drawdown: the difference, measured in feet or meters, between the water table or static water level and the level of the water after pumping.

Electrical Conductivity: a chemical parameter that quantifies the potential for water to conduct or carry electricity. Electrical conductivity is a function of the the quantity of dissolved minerals (particularly salt) in the water.

General Bacteriology: water quality analysis performed to determine the presence of bacteria and sometimes to determine the amount of fecal material present in a sample.

Holding Time: the amount of time between sample collection and when a laboratory needs to analyze the sample. For example, for fecal coliform samples, less that 24 hours can pass between sampling activities and analysis or the data will be invalid.

JORDANLAB: analytical laboratory in San Pedro Sula used to analyze samples for the USAID project.

Preservatives: chemicals—typically acids—added to sample bottles collected in the field to increase the time allowable between sampling and analysis. Preservatives are also used to retain potential contaminants in the sample so the laboratory can get a true understanding of what is in the water.

Radiological Chemicals (Gross a, Gross ß): chemical parameters used to demonstrate the amount of radiological chemicals in a sample.

Screening: the portion of PCV or steel casing that is perforated to allow the passage of aquifer water into the well.

Sounder: a device used to determine the level of water in the well. It measures feet or meters below ground surface.

SPL: Southern Petroleum Laboratories, laboratory used for the USAID Groundwater Resources Study for metals, radiological chemicals, pesticides and herbicides and VOCs.

Static Water Level: the level at which water stands in a well or unconfined aquifer when no water is being removed from the aquifer etiher by pumping or free flow.

QA/QC: Quality Assurance/Quality Control, a method of checking data to be sure it is valid.

Volatile Organic Chemicals: man-made organic chemicals that are widely used for industrial and domestic purposes including solvents for cleaning and pesticides/herbicides.

Tabla No.1 Pozos seleccionados para muestreo en los municipios de Villanueva, La Lima, Choloma

Nombre del Pozo	Municipio	UTM	Q GPM	Fuente de contaminación	Profundidad del Pozo (Pies)	Profundidad Rejilla (pies)	Llave para muestreo	Elevación Terreno natural	Sector abastecido No. de Viviendas Abastecidas	Producción Diaria (Gal)
La Victoria	Villanueva	16P 0394395 1693962	120	Ninguna	195		SI	67.3278	Col. La Victoria 543	172,800
Pintala I	Villanueva	16P 0392752 1691490	400	Ninguna	240	41	SI	53.3728	Col. 1 de Mayo y San Antonio 96	48,000
Manuel Coello	Villanueva	16P 0394328 1692334	202	Ninguna	270	49	SI	50.1758	A tanque Col. Victoria y Col. Sitrahmacs 543	115,140
Villa Linda Norte	Villanueva	16P 0394962 1695873	105	Letrinas a 10 metros	300	25	SI	54.1698	Col. Villa Linda Norte 144	25,200
Villa Sol	Villanueva	16P 0393671 1693850	27.24	Ninguna	184		SI	78.8138	Parte de la Col. Villa Sol 40	37,591
Cañeras II	Villanueva	16P 0393345 1691699	600	Ninguna	250	100	SI	47.2048	Conectado al Plan Maestro (Red baja y alta) 3369	864,000
Guadalupe Lopez	Villanueva	16P 0396098 1693853	150	Letrinas a 10 metros	260	70	SI	70.7248	Tanque 21 de Abril 315	216,000
22 de Mayo	La Lima	16P 0391650 1709438	90	Letrinas a 5 metros	180		SI	29.238	Tanque Col. 22 de Mayo 105	97,200
Villa Esther	La Lima	16P 0402604 17006467	200	Canal de aguas negras a 100 metros	260	154	SI	26.83	Residencial Villa Esther 9	252,000
Oro Verde	La Lima	16P 0403573 1705732	298	canal de aguas negras a 100 metros			SI	25.43	Residencial Oro Verde y Zip Continental	
Guaymuras	La Lima	16P 0397437 1708534	100	Letrinas a 30 metros	362		SI	28.937	A Tanque Guaymuras 155	108,000
Planeta #1 (Fusep)	La Lima	16P 0398234 1709076		Ninguna	200	40	SI	28.091	Red de la Col. Planeta 2312	
La Mesa (Nuevo)	La Lima	16P 0401055 1708035	400	Ninguna	200	63		27.755	Col. La Mesa NO HAY BOMBA	
Cruz Roja	La Lima	16P 0400429 1707065	150	Ninguna	200	150	SI	27.87	A la red del Centro de Lima Vieja	162,000
Martinez Rivera	La Lima	16P 0400140 1705694	150	Ninguna	180		SI	28.993	Tanque de la Col. Martinez Rivera 101	162,000
San Carlos	Choloma	16P 0399179 1726619	296	Ninguna	176	41	SI	26.223	Tanque de la Col. San Carlos 885	337,400

Nombre del Pozo	Municipio	UTM	Q GPM	Fuente de contaminación	Profundidad del Pozo (Pies)	Profundidad Rejilla (pies)	Llave para muestreo	Elevación Terreno natural	Sector abastecido No. de Viviendas Abastecidas	Producción Diaria (Gal)
Prado I	Choloma	16P 0399065 1728223	60	Quebrada con aguas negras a 75 metros	100		SI	26.298	Tanque de la Col. Prado I 161	14,400
Residencial Europa	Choloma	16P 0399366 1725680	225	Ninguna	117		SI	24.423	Tanque de la Col. Europa 389	283,500
San Antonio	Choloma	16P 0397599 17267087	450	Contaminación por infiltración de heces fecales	120	60	SI	33.852	A la red del centro de Choloma	648,000
Bella Vista	Choloma	16P 0398794 1725376	196.2	Quebrada contaminada por aguas negras 400 metros	200		SI	27.282	Sector Sur (Sector López Arellano) 2751	282,528
Bomberos I	Choloma	16P 0397867 1726032	257.2	Ninguna	200	40	SI	32.422	Sector SE, SO, NE de Choloma	370,368
San Francisco	Choloma	16P 0397287 1726970	100	Quebrada contaminada por aguas negras a 1 metro	80		SI	37.315	Col. Los Almendros y Col. Care 439	108,000
Barrosse II	Choloma	16P 0398472 1728223	587	Ninguna	200	60	SI	25.813	Sector N.O. de Choloma	845,280
Victoria (Gas. Depesa)	Choloma	16P 0397645 1721746	68	Ninguna	329	40	SI	52.523	A tanque Col. La Victoria 90	24,480
Canada	Choloma	16P 0397831 1725769	400	Canal de aguas negras a 30 metros y quebrada contaminada con aguas negras y desechos de fabricas a 150 metros	200		SI	31.992	A la red de la Col. Canadá 127	576,000.00
Parque Central	Choloma	16P 0397918 1726067	350	Ninguna	200		SI	32.077	A la red del centro de Choloma	420,000
Primavera	Choloma	16P 0397194 1726282	180	Ninguna	200		SI	36.434	Col. La Primavera 312	259,200

Tabla No.2 Método Analítico, Envase, y Especificaciones de Control de Calidad para Villanueva, Cortés, Honduras.

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	No. de Envases	Preservantes	Duplicado	MS	MSD
Cañeras 2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
	A.S.	Pesticidas/Herbicidas	32 oz. Ámbar	2	Ninguno			
Pintala 1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Pintala 2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Plástico	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Guadalupe Lopez 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno	X	X	X
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno	X	X	X
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio	X	X	X
Manuel Coello 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Colonia Victoria 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Plástico	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Villa Linda Norte	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
BC-VI-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
BC-VI-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Plástico	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-VI-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-VI-4 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
	A.S.	Total a, Total ß	32 oz. Plástico	2	Ácido Nítrico			
BC-VI-5 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			

Tabla No.3 Método Analítico, Envase, y Especificaciones de Control de Calidad para Choloma, Cortés, Honduras.

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	Número de Envases	Preservantes	Duplicado	MS	MSD
Parque Central 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Bomberos 1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Bella Vista 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Perez Estrada 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
San Carlos 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Res. Europa 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Col El Prado II 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Barrosse 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno	X	X	X
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno	X	X	X
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio	X	X	X
San Antonio 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
San Francisco 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
La Primavera 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
Victoria 1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
Inez Carranza Barnica 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
Res. América 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-CH-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-CH-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
	A.S.	Total a, Total ß	32 oz. Plástico	2	Acido Nítrico			
BC-CH-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			

Tabla No.4 Método Analítico, Envase, y Especificaciones de Control de Calidad para La Lima, Cortés, Honduras

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	Número de Envases	Preservantes	Duplicado	MS	MSD
Don Lolo 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Oro Verde 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Martínez Rivera 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
22 de Mayo 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Guaymuras 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Villa Esther 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Planeta Fusep 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno	X	X	X
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno	X	X	X
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio	X	X	X
Cruz Roja 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Vivero Municipal 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-LL-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	32 oz. Plástico	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-LL-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
	A.S.	Total a, Total ß	32 oz. Plástico	2	Ácido Nítrico			
BC-LL-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			

Tabla No.5 Método Analítico, Envase, y Especificaciones de Control de Calidad para Limón de la Cerca, Choluteca, Honduras.

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	Número de Envases	Preservantes	Duplicado	MS	MSD
Panamerica LC4 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Bolsa Samaritana LC3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Ricardo Soriano LC1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Iglesia Cristo Rey 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Atlas LC2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Luis 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
BC-LC-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-LC-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
	A.S.	Total a, Total ß	32 oz. Plástico	2	Ácido Nítrico			
BC-LC-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			

Tabla No. 6 Red de Monitoreo de Pozos
La Lima, Honduras

No	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (m snm)	Elevación Nivel de Referencia (m snm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estatico (m)	Fecha lectura	Observaciones
1	Colonia Fraternidad	16P 0399855 1707090	Observación	28.06	28.38	15.00	04-Oct-01			
2	Los Maestros	16P 0400224 1707203	Monitoreo	27.19	27.62	6.79	06-Sept-01			
3	El Mixto	16P 0400700 1706883	Procucción	28.51	29.42	6.67	04-Jan-02			
4	Cruz roja	16P 0400469 1707065	Procucción	27.87	28.37	12.88	04-Jan-02			
5	Sitraterco	16P 0400587 1707306	Procucción	27.57	28.01	8.56	04-Jan-02			
6	Martínez Rivera	16P 0400135 1705691	Procucción	28.99	29.05	4.54	04-Jan-02			
7	Gabriela Mistral	16P 0400294 1706908	Procucción	28.45	29.11	5.64	06-Jan-01			
8	Zapote No.1	16P 0398158 1706728	Procucción	31.09	31.75	4.95	04-Jan-02			
9	Zapote No.2	16P 0397798 1706836	Procucción	30.57	31.17	3.35	04-Jan-02			
10	Planeta No.1 (Fusep)	16P 0398803 1708994	Procucción	28.09	28.39	5.97	04-Jan-02			
11	Planeta No.3	16P 0398284 1709356	Procucción	27.89	28.16	6.46	04-Jan-02			
12	FHA No.1 (Fuerza Aérea Hondureña)	16P 0399594 1707531	Monitoreo	27.41	27.98	5.50	04-Jan-02			
13	FHA No.2 (Fuerza Aérea Hondureña)	16P 0399624 1707517	Monitoreo	27.31	27.61	4.10	04-Jan-02			
14	Aeropuerto	16P 0399349 1707864	Monitoreo	26.51	26.67	6.67	04-Jan-02			
15	Jerusalem No.1	16P 0397548 1709059	Procucción	28.48	28.76	5.50	04-Jan-02			

No	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (msnm)	Elevación Nivel de Referencia (msnm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estatico (m)	Fecha lectura	Observaciones
16	Jerusalem No 2 (Kinder)	16P 0397368 1708923	Procucción	28.42	28.60	7.10	04-Jan-02			
17	Guaymuras	16P 0397437 1708534	Procucción	28.94	29.99	8.85	04-Jan-02			
18	San Cristobal	16P 0397715 1708758	Procucción	29.37	31.45	13.60	04-Jan-02			
19	La Paz No 2 (Luis Thiebaud)	16P 0400263 1706706	Procucción	25.90	26.41	7.21	04-Jan-02			
20	Oro Verde	16P 0403573 1705732	Procucción	25.43	25.72	4.02	04-Jan-02			
21	Villa Esther	16P 0402604 1706467	Procucción	26.83	27.11	9.25	04-Jan-02			

Tabla No. 7 Red de Monitoreo de Pozos
Choloma, Honduras

No.	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (msnm)	Elevación terreno Referencia (msnm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estático (m)	Fecha lectura	Observaciones
1	San Francisco	16P 0397287 1726970	Producción	37.32	37.66	5.97	17-Dec-01			
2	San Antonio	16P 0397599 1726708	Producción	33.85	34.39	5.14	17-Dec-01			
3	Primavera	16P 0397194 1726282	Producción	36.43	36.68	5.74	17-Dec-01			
4	Prado I	16P 0399065 1728223	Producción	26.30	26.49	5.92	05-Dec-01			
5	Prado II	16P 0399065 1725620	Producción	25.61	26.21	5.76	05-Dec-01			
6	Residencial El Japón	16P 0400206 1725865	Producción	21.42	21.77	4.27	05-Dec-01			
7	Inés carranza Barrica	16P 0398277 1720762	Producción	42.23	42.74	13.86	18-Dec-01			
8	Bomberos I	16P 0397867 1726032	Producción	32.42	33.61	9.90	17-Dec-01			
9	Residencial San Carlos	16P 0399179 1726619	Producción	26.22	26.30	4.92	05-Dec-01			
10	Residencial América	16P 0399292 1726913	Producción	26.92	27.26	3.98	05-Dec-01			
11	Victoria #1 (gasolinera)	16P 0397645 1721746	Producción	52.52	52.94	21.32	18-Dec-01			
12	Residencial Europa	16P 0399366 1725680	Producción	24.42	24.92	4.10	05-Dec-01			
13	Canadá	16P 0397831 1725769	Producción	31.99	33.87	9.61	17-Dec-01			
14	La Mora No.1	16P 0396909 1725541	Producción	35.78	35.96	10.77	18-Dec-01			

Tabla No. 8 Red de Monitoreo de Pozos
Villanueva, Honduras

No.	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (m snm)	Elevación terreno Referencia (m snm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estático (m)	Fecha lectura	Observaciones
1	Orquidea II	16P 0393142 1694141	Producción	92.66	92.82	33.80	29-Nov-01			
2	Orquidea III	16P 0393034 1694095	Producción	94.51	94.95	43.56	29-Nov-01			
3	Col. Municipal	16P 0395157 1694522	Producción	64.93	65.50	10.60	29-Nov-01			
4	Buena Vista	16P 0395939 1693554	Producción	71.48	72.09	34.43	29-Nov-01			
5	Villa Linda Norte	16P 0394962 1692873	Producción	54.51	54.96	13.50	29-Nov-01			
6	Guadalupe Lopéz	16P 0396098 1693853	Producción	71.10	71.40	30.17	29-Nov-01			
7	La Victoria	16P 0394395 1693962	Producción	67.98	68.76	32.66	29-Nov-01			
8	Cañeras II	16P 0393445 1691699	Producción	47.51	47.91	10.94	06-Julio-01			
9	Pintala I	16P 0392752 1691490	Producción	53.37	53.78	8.77	29-Nov-01			
10	Villasol	16P 0393671 1363850	Producción	71.81	72.04	28.17	30-Nov-01			
11	Independencia I	16P 0393832 1693445	Producción	72.52	73.02	23.00	30-Nov-01			
12	Manuel Coello	16P 0394328 1692334	Producción	50.18	50.56	14.57	20-Nov-01			
13	Vivero Municipal	16P 0393415 1694607	Producción	97.28	97.48	32.64	29-Nov-01			
14	Llanos de Canadá	16P 0395814 1692807	Producción	52.00	52.84	6.49	19-Julio-01			
15	Zip Villanueva #6	16P 0394991 1694016	Producción	61.73	63.93	18.32	18-Julio-01			

APPENDIX A

Field Form

WATER SAMPLE DATA LOG

Project No.:	Project:
Well No.:	Date:
Location:	Weather:
Purpose of Sampling Event:	

WELL DATA

Total Depth of Well (ft bls):	Depth to Water (ft bls):
Screened Interval (ft bls):	Date/Time:
Casing Diameter (in):	Pt. of Measurement:

FIELD SAMPLING DATA

Time	Discharge Rate (gpm)	Total Discharge (gallons)	pH	Temp. °F	Specific Conduct. (µmhos/cm)	Sand Content (mL/l)	Comments

Time Pumping Started: ____________ Time of Sample Collection: ____________

Type of Samples Collected: ____________

Total Discharge (gpm): ____________ Type of EC-T-pH Meter: ____________

Sample Collected by: ____________

How Sample Collected: ____________

Comments: ____________

APPENDIX B

Chain of Custody

SPL, Inc.

Analysis Request & Chain of Custody Record

SPL Workorder No: 104520

page 1 of 1

Client Name: Brown & Caldwell

Address/Phone: Barbara Goodrich

Client Contact: 925-937-9010

Project Name: USAID Groundwater Monitoring

Project Number: 21365

Project Location: Villanueva, Cortés, Honduras

Invoice To: Brown & Caldwell, Walnut Creek

SAMPLE ID	DATE	TIME	comp	grab	matrix (W=water S=soil SL=sludge O=other:)	bottle (P=plastic A=amber glass G=glass V=vial)	size (1=1 liter 4=4oz 40=vial 8=8oz 16=16oz)	pres. (1=HCl 2=HNO3 3=H2SO4 O=other:)	Number of Containers	Requested Analysis: metales	coliformes	VOCs								
nombre de muestra	11/30/2001	1420		X	W	P	1	–	1	X										
nombre de muestra	11/30/2001	1425		X	W	G	16	1	1		X									
nombre de muestra	11/30/2001	1425		X	W	G	40	3				X								

Barbara Goodrich

Client/Consultant Remarks:

Laboratory remarks:

Intact? ☐ Y ☐ N

Temp:

Requested TAT

24hr ☐ 72hr ☐

48hr ☐ Standard ☒

Other ☐ ______

Special Reporting Requirements: Fax Results ☒ Raw Data ☐

Standard QC ☒ Level 3 QC ☐ Level 4 QC ☐

Special Detection Limits (specify):

PM review (initial):

1. Relinquished by Sampler: Barbara Goodrich to DHL	date 11/30/2001	time 1750	2. Received by:
3. Relinquished by:	date	time	4. Received by:
5. Relinquished by:	date	time	6. Received by Laboratory:

☒ 8880 Interchange Drive, Houston, TX 77054 (713) 660-0901

☐ 500 Ambassador Caffery Parkway, Scott, LA 70583 (318) 237-4775

☐ 459 Hughes Drive, Traverse City, MI 49684 (616) 947-5777

APPENDIX C

Groundwater Sampling Event Checklist

CHECKLIST FOR GROUNDWATER SAMPLING EVENT

<u>Before leaving for the field:</u>

1. Contact the laboratory responsible for bacteriological analysis before sampling event.
2. Arrangements made for international transport of water samples.
3. Access to well and proper pump function have been verified before water sample.
4. The following materials and equipment are available:
   Electronic water level meter
   Field meter for conductivity, pH, and temperature
   Field meter calibration solutions
   Water sample containers (supplied by laboratory)
   Ice chests
   Ice
   Water sample labels
   Disposable gloves
   Zipper-lock plastic bags
   Water sampling field forms
   Chain of custody form
   Camera and film
   Sample packing material
   Water sample field filtering equipment
   Flame disinfection equipment
5. Confirm proper function of the electronic water level meter

<u>In the field:</u>

1. Observation and proper documentation of conditions at the well site prior to sampling.
2. Locate elevation reference point for water level measurement.
3. Conduct three consecutive measurements of groundwater level and record results on the field data form.
4. Disinfection of the sampling port using flame.
5. Proper purging of three well volumes before water sampling.
6. Calibration of the field conductivity, pH, and temperature meter.
7. Measurement of conductivity, pH, and temperature and documentation in field form.
8. Water sampling personnel use disposable gloves during water sampling.
9. Collection of the necessary quantity of groundwater for each analysis.
10. Samples for iron and magnesium analysis were filtered in the field.
11. Sample containers for volatiles analysis were free of bubbles.
12. Sample date and time are recorded and documented on field form.
13. All samples are properly labeled.
14. Chain of custody documentation is filled out prior to sampling of next well.
15. Periodic confirmation that water sample ice chest contains sufficient ice to maintain a temperature not greater than 40 C.

After water sampling:

1. Water samples for bacteriological analysis were delivered to the laboratory within the appropriate holding time.
2. The laboratory signed the chain of custody for receipt of water samples.
3. Water samples for shipment were carefully packed in protective material, preferably bubble-wrap.
4. Ice for the ice chest is placed in zipper-lock plastic bags to avoid spilling.
5. Water samples and ice are placed in a large plastic bag within the ice chest.
6. The signed and dated chain of custody is placed in the ice chest for shipping.
7. The ice chest was carefully sealed prior to shipping.
8. An international air bill and a commercial invoice are filled out to accompany the ice chest during shipping and transport.
9. The laboratory in Houston was contacted to notify of the shipment, the number of samples in the shipment, the requested analyses, and the estimated time of arrival of the shipment.

APPENDIX D

Photographs

Containers for water samples

Water level sounder

Temperature, pH and conductivity meter


Flame cleaning of sampling port prior to sample collection

Field filtering of water samples to be analyzed for dissolved iron and manganese

Cleaning of sampling port

APPENDIX F

Wellhead Protection Plan

WELLHEAD PROTECTION PLAN

Villanueva, Honduras

June 2002

INTRODUCTION

The most effective means in protecting the groundwater quality used for public water supply in Villanueva is establishing a wellhead protection program. Wellhead protection is the practice of managing the land area around a well to prevent groundwater contamination. Prevention of groundwater contamination is essential to maintain a safe drinking water supply.

The control measures included in this section should be incorporated into municipal regulations to ensure control on water use and to protect the area covered with dense vegetation that represents potential groundwater recharge areas through rainfall infiltration.

Groundwater may become contaminated through natural sources or numerous types of human activities. One of the main causes of groundwater contamination induced by human activity is the effluent from septic tanks, cesspools, and latrines. Although each disposal system releases a relatively small amount of waste into the ground, the large number and widespread use of these systems results in a significant contamination source. Similarly, improper disposal of gray water, hazardous wastes, leaking fuel storage tanks, and chemical storage and spill sites are sources of contamination to groundwater.

KEY STEPS

Development of a wellhead protection plan for Villanueva consists of five key steps that are described in detail below:

Step 1: Planning. The municipality should assemble a team to arrive at a cooperative effort for wellhead protection objectives. The team may include municipal officials, representatives from the public works departments, environmental managers, and members from the local health department.

Team objectives should focus on delineation of a wellhead protection area to protect the water wells from unexpected contaminant releases, as well the development of a plan for controlling high-risk activities within the well recharge area.

Step 2: Delineate the Wellhead Protection Area. The geographic limits most critical to the protection of a well water supply must be delineated. Based on this information, a base map should be developed that shows detailed information on the natural features of the area, both surface and subsurface, land use including roadways and utilities, and location of all public supply wells and water recharge areas. Clear acetate overlays can be added that illustrate the radius of influence (even if estimated) for every pumping residential and municipal water supply well, location of aquifers and aquifer recharge zones, watershed in which the aquifers are located, wetlands, lakes and flood zones that may affect recharge, and potentiometric surface information that illustrates groundwater flow direction.

The actual delineation of a wellhead protection area ranges in complexity from drawing a circle of specified radius around each well, to more sophisticated techniques involving analytical methods and groundwater modeling. Using an arbitrary fixed radius - calculating a fixed radius measured from the well to the wellhead protection area boundary - is an inexpensive, easily implemented method of wellhead delineation. Choosing a large fixed radii will increase the protective effectiveness, but alternatively, could lead to overcompensation and unnecessary wellhead protection costs. However, a disadvantage of the fixed radius approach is that it is not based on hydrogeologic principles and could lead to inadequate protection of recharge areas. Given the limited aerial extent of the freshwater aquifer at Villanueva, the entire area may be included inside the protection zone.

Step 3: Identify and Locate Potential Sources of Contamination. The objective of this step is to prepare a master wellhead protection area map that shows all existing contaminant sources and identifies potential threats. First, a comprehensive inventory of potential and known contaminant sources should be developed within each wellhead protection area. Sources should include past and present waste sites such as sewage treatment and disposal areas, landfills, and chemical storage and disposal areas, including small commercial and any future industrial waste areas. The inventory should also include agricultural sources such as crops where pesticides and insecticides may have been used, animal feedlots, livestock waste disposal areas, and agricultural drainage ditches and canals. In addition, residential areas with septic systems, latrines, cesspools, and buried waste disposal areas should be inventoried. Once all of the potential sources of contamination have been identified, each source should be plotted on an overlay of the wellhead protection area.

Following identification of source areas, an evaluation of the immediacy and degree of risk associated with each potential source of contamination should be conducted. Values of risk can be assigned and ranked based on their proximity to groundwater supply, the nature of the contaminant, and the intended use of groundwater. By assigning risk values, it is possible to prepare a map illustrating the location and magnitude of potential threats to the groundwater supply, as well as aid in determining which areas require immediate attention to prevent contamination to the water supply.

Step 4: Manage the Wellhead Protection Area. A long term, low cost management wellhead protection plan can be tailored for the municipality. It may be initiated by addressing identified immediate threats to the groundwater supplies followed by a program of prevention and protection of future supplies. One easily achieved component of the plan is to institute a public education program to increase awareness of the threats of groundwater contamination and encourage groundwater protection and conservation measures. Other programs may include the municipality acquiring sensitive recharge areas and converting them to park land, recreational facilities, or other community-based land uses.

Another component of wellhead protection is groundwater monitoring. Regular groundwater monitoring around municipal and residential water supply wells can detect potential sources of contamination before they infiltrate the municipal water supply. A good groundwater monitoring program consists of collecting numerous groundwater samples on a regular basis and performing laboratory tests to detect various contaminants, which will identify problems quickly. The further the monitoring wells are located from the pumping well, the sooner problems can be identified and more time will be available to rectify the situation or provide adequate substitute water supplies.

Step 5: Plan for the Future. A critical component of a successful wellhead protection plan is regular annual review and update of the plan. This will allow for improvement of management strategies and provide time to act on new information regarding sources of contamination. A critical aspect of the plan is the identification of future hazards that could threaten the wellhead protection areas. Early identification will allow time to develop solutions or contingency plans for alternate water supplies.

APPENDIX G

Training and Workshops

TRAINING AND WORKSHOPS

Villanueva, Honduras

June 2002

INTRODUCTION

Brown and Caldwell conducted a series of workshops and training sessions throughout the project. These sessions consisted of project kick-off, status meetings, training sessions, and project wrap-up meetings, as described below.

Project Kick-off and Status Meetings

Initially, Brown and Caldwell held two project kick-off meetings to introduce the project to interested stakeholders and build consensus regarding project objectives. The kick-off meetings were held in Tegucigalpa on 3 May 2001 and in San Pedro Sula on 22 May 2001. Kick-off meeting agendas and lists of attendees are included at the end of this section.

On 11 July 2001, Brown and Caldwell held a workshop to present the conceptual hydrogeologic models we developed for each of the study areas and update interested parties on the status of the project. This meeting was held in San Pedro Sula. A workshop agenda and list of attendees is also included at the end of this section.

Training Sessions

To help ensure project sustainability, Brown and Caldwell held seminars to train local municipal personnel in groundwater monitoring techniques and in operating the water resource database developed for each project municipality. Groundwater monitoring training sessions were held on December 4th, 6th, and 10th, 2001 at Limon de la Cerca, the Sula Valley, and Utila, respectively. A training session agenda and list of municipal personnel who participated in the training is included at the end of this section. The training sessions on how to use and update the project databases developed by Brown and Caldwell were held in San Pero Sula and Tegucigalpa on February 12th and 14th, respectively. These training sessions were held at the local UNITEC campuses. Again, a training session agenda and list of attendees is included at the end of this section.

Project Wrap-Up Meetings

The project also calls for project wrap-up meetings to be held with mayors and other representatives of each municipality. These meetings are intended to help ensure project sustainability by introducing the project to the new municipal governments, discussing project results, and making recommendations for implementing components of the water resource management plans developed for each municipality. Although these meetings were not completed at the time of the writing of this report, the meetings were scheduled as follows:

Limon de la Cerca/Choluteca – 20 June 2002
Isla de Utila – 22 June 2002
Choloma – 24 June 2002
La Lima – 25 June 2002
Villanueva – 26 June 2002.

A copy of the agenda for the wrap-up meetings is included at the end of this section.

PROJECT KICK-OFF AND STATUS MEETINGS

AGENDA
May 3, 2001 Kickoff Meeting – Tegucigalpa
USAID Groundwater Monitoring (Water Resource Management) Studies
Choloma, La Lima, Limón de la Cerca, Utila, Villanueva

I. Introduction
   A. USAID Project Background (audience introductions)
   B. Brown and Caldwell Project Team

II. Project Goals and Objectives – Jeff Nelson
   A. Background
   B. Meeting Objectives (consensus)
   C. Project Objectives (sustainability)
   D. Scope of Work/5 Phases
   E. Municipality Needs

III. Program Implementation – Horacio Juarez
   A. Development of Partnerships
   B. Sustainability
   C. Project Schedule

10:30 – 10:45 Coffee Break

IV. Project Overview – Jim Oliver
   A. Conceptual Model
   B. Hydrogeology
   C. Modeling
   D. Matrix Prioritization

V. Water Resource Management Plans – Paul Selsky
   A. Water Needs
   B. Water Supply and Delivery
   C. Recommendations
   D. Management Plan Development

12:00 – 1:30 Lunch Break

VI. Municipality Input – Audience

VII. Technical Approach – Jay Lucas/Milton Sagustume
   A. Phases (update)
   B. Drilling
   C. Project Schedule

3:00 – 3:15 Coffee Break

VIII. Data Base – Allan Scott
   A. USGS Data Base
   B. Project GIS
   C. Technology Transfer and Training

IX. ReCap and Open Discussion
   A. Consensus

5/3/2001

Name	Organization	Phone Number
ALLAN SCOTT	BROWN + CALDWELL	916 853-5380
Barbara Goodrich	Brown & Caldwell	925-210-2345
Francisco Casco	Municipalidad Villanueva	504-670-[illegible]
Ramón Jiménez Flores	Municipalidad Villanueva	670-44-45
Rodolfo Ochoa	SANAA.	2206506
Carlos M. Flores	USAID	236-9320-X-44[illegible]
Paul Selsky	Brown & Caldwell	
Alicia Villar Landa	PRIMHOR	239-41-14/41-8[illegible]
Maurice James	U.S. Army Corps of Engineers	991-9189
Mauricio Cruz	USAID	236-9320 (479[illegible]
Carlos Verdial	USAID	236-9320 (40[illegible]
Juan Benito Guevara	Alcaldía El Progreso	882-7171
John Walker	USGS	9928312
Olman O. Rivera	USACE-USAID	995.74-79
Jason Grant	Brown and Caldwell	925-210-2383
Mario A. Flores	Fundemun	
César H. Monroy	Fundemun	882-4298
Ricardo Valle	FUNDEMUN.	985 4930
James Oliver	Brown & Caldwell	602-222-4463
Alfredo Stein	Embajada de Suecia	221.1736
DAVID BOURAN	USAID (dbouran@usaid.gov)	236-9320 (466
ARCELIA SALGADO	USAID (a.salgado@usaid.gov)	236-9320 (4663
Jeff Nelson	Brown & Caldwell jnelson@brwncald.com	988-5927 (cell)
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Jorge Flores	FHIS	2348619 / 99 633
Isidro Alberto Mondragon	Fundemun	882-429[illegible]
HORACIO JUAREZ	BROWN & CALDWELL	(915) 545-44[illegible] 188-593[illegible]

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Lisa Pacholek	CHF	LPacholek_CHF@cablecolor.hn
Karen Perez	Brown & Caldwell	983-1604

AGENDA
22 de Mayo 2001
Estudio y Monitoreo de Aguas Subterráneas (Manejo de Recursos de Agua)
Los Municipios de Choloma, La Lima, Limón de la Cerca, Utila, Villanueva
Financiado por USAID

I. Introducción – Ing. Carlos Flores
    A. Antecedentes del Proyecto USAID (Presentación de los Participantes)
    B. Presentación de Brown and Caldwell y el equipo técnico del Proyecto

II. Metas y Propósitos del Proyecto – Ing. Jeff Nelson
    A. Antecedentes
    B. Propósitos de la Reunión (consenso)
    C. Propósitos del Proyecto (sostenibilidad)
    D. Alcance del Trabajo (cinco fases)

III. Implementación del Programa – Ing. Horacio Juarez
    A. Desarrollo de Asociaciones entre Agencias Participantes
    B. Sostenibilidad
    C. Programa del Proyecto

IV. FUNDEMUN – Ing. Jenny Chávez
    Aplicación de Tasas de Cobre por Explitación de Aguas Subterráneas según Plan de Arbitrios

    DESCANSO (Quince minutos)

V. Resumen de Actividades del Proyecto
    A. Evaluación de Sistemas Existentes y Recopilación de Datos – Ing. Dean Wolcott
    B. Base de Datos Hidrogeológicos – Lic. Dean Wolcott
    C. Modelación Hidrogeológica – Ing. Milton Sagastume
    D. Manejo de Recuros Hídricos – Ing. Milton Sagastume
    E. Programa de Perforación de Pozos – Ing. Milton Sagastume

VI. Comentarios por parte de Alcaldes, Gerentes o Jefes de Servicios

US AGENCY FOR INTERNATIONAL DEVELOPMENT
USAID/Honduras

Tegucigalpa, M.D.C.
21 de mayo de 2001

A QUIEN INTERESE

De todos es conocido, que cada vez es más frecuente y significativa la utilización y explotación de acuíferos subterráneos para satisfacer las demandas de agua de las poblaciones de varias comunidades y ciudades alrededor del país. Por lo que es fácilmente previsible que el uso de las aguas subterráneas para el abastecimiento de agua potable en estas localidades, se incrementará en la misma medida que haya un crecimiento de la población futura y por lo tanto los rendimientos de estos acuíferos se verán disminuidos en una mayor proporción.

Los sistemas de abastecimiento de agua de las ciudades de La Lima, Choloma y Villanueva en el valle de sula, de la Isla de Utila y de Choluteca, que utilizan las aguas subterráneas como principal fuente de abastecimiento, fueron severamente dañados durante el paso del Huracán Mitch. Actualmente, la Agencia Internacional para el Desarrollo de los Estados Unidos (USAID) realiza fuertes inversiones en estas regiones para construir nuevos centros habitacionales y para rehabilitar y a su vez expandir los sistemas de abastecimiento de agua respectivos.

Recientemente, la USAID ha contratado los servicios de la Firma Consultora Brown and Caldwell para elaborar un estudio de monitoreo de aguas subterráneas en las ciudades arriba mencionadas. El desarrollo de dicho proyecto conlleva el realizar estudios hidrogeológicos, recopilar una base de datos que provea información suficiente para implementar planes prácticos y efectivos en la administración del recurso agua subterránea en cada localidad y determinar si este recurso cumple y satisface adecuadamente las expectativas y requerimientos de demanda actual y futura. Así mismo, el Estudio contempla realizar una evaluación preliminar de la infraestructura de abastecimiento de agua subterránea existente en cada municipalidad y desarrollar costos estimados preliminares para el mejoramiento de esta infraestructura.

El éxito de este proyecto será medido al asegurar la sostenibilidad de los objetivos planteados en el mismo, una vez que éste finalice. Por lo tanto, un componente fundamental para asegurar dicha sostenibilidad será el de crear relaciones de trabajo permanentes entre el Consultor y cada una de las municipalidades involucradas, así como con otros organismos y/o instituciones relacionadas con el tema de aguas subterráneas, como ser SANAA, FUNDEMUN, Acción Contra el Hambre, UNITEC y la Comisión Ejecutiva del Valle de Sula. Dentro de este contexto, cabe mencionar que es menester de la Municipalidad designar el recurso humano necesario para que sea debidamente

Mailing Addresses: From USA: USAID/Honduras, UNIT 2927, APO AA 34022. Tel. 011-504-236-9320
In Honduras: Apartado Postal 3453, Tegucigalpa, M. D. C. Tel. 236-9320, Fax (504) 236-7776

capacitado por la Firma Consultora en el manejo, seguimiento y monitoreo del modelo y de la base de datos que será proporcionada a la Municipalidad.

En base a lo anterior, solicitamos su gentil cooperación para proporcionar toda aquella información que usted estime conveniente a la Firma Brown & Caldwell, la cual ha sido contratada para elabora este estudio. Su cooperación y asistencia son vitales para alcanzar el éxito y garantizar los futuros recursos de agua subterránea en Honduras.

Atentamente,

Todd Sloan
Director
Oficina de Desarrollo Municipal
e iniciativas Democráticas

USAID

BROWN AND CALDWELL

Lista de Invitados

22 de Mayo 2001

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9	Rigoberto Rivera C	Municip de Villanueva	670-58-80	
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11	Silvia Fernandez	Regidora La Lima	991-6547	DIFzeloya@
12	MONTERREY CARDENAS	Municipalidad de Utila	425-3293	—
13	Juan Ramon Mejia A.	Municipalidad Choloma	669.39.22	— " —
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38	Mario Ramón Jiménez Soto		651 27 35	

Lista de Invitados

22 de Mayo 2001

USAID

BROWN AND CALDWELL

No.	Nombre	Empresa/Corporación	Teléfono	E-mail
	German Wilfredo Henriquez	Municipalidad Rama	6682480	

AGENDA
USAID Monitorio y Estudios de Aguas Subterráneas
Presentación del Modelo Conceptual Hidrogeológico Preliminar
Utila, Valle de Sula y Limón de la Cerca

11 de Julio 2001
9:30 a.m.
Hotel Princess
San Pedro Sula

I. INTRODUCCION

II. RECURSOS DE AGUA EXISTENTES
  A. Fuentes de Agua
  B. Localización de Pozos

III. MODELOS CONCEPTUALES HIDROGEOLOGICS PRELIMINARES
  A. Geología
  B. Hidrogeología

IV. DATOS
  A. Geología
  B. Hidrogeología
  C. Calidad de Agua
  D. Modelación
  E. Información del Sistema de Agua

V. FASE II INVESTIGACION DE CAMPO
  A. PERFORACION
    1. Pozos de Prueba
    2. Aquíferos de Prueba
    3. Muestreo y Análisis de Agua

  B. ESTUDIOS GEOFISICOS
    1. Estudios EM
    2. Estudios Sísmicos y Reflexión

VI. EVALUACION DE LA INFRAESTRUCTURA DEL SISTEMA DE AGUA
  F. Población
  G. Uso de Agua
  H. Facilidades de Sistema de Agua

VII. DISCUSION

11 de Julio 2001
Invitee List

VILLANUEVA MUNICIPALITY 670-4788/670-4445

1. Lic. José Felipe Borjas (Alcalde Municipal)
2. Lic. Francisco Casco (Jefe de Obras y Servicios Públicos)
3. Lic. Rigoberto Rivera (Jefe de Servicios Públicos)
4. Juan Pago Avila (Jefe de Departamento de Agua)
5. Alfredo Cabrera (Jefe de Operación de Mantenimiento)
6. Ramón Jímenez Flores
7. Hector Cabrera

LA LIMA MUNICIPALITY 668-2400/668-2601

1. Lic. Evaristo Euceda (Alcalde Municipal)
2. Ing. Doris Pérez (Directora de Servicios Públicos)
3. Ruben Saravia (Jefe de Servicios Públicos)
4. Ing. Aurora Rodríguez (Asistente)
5. Jorge Nery López (Asistente Departamento de Catastro)
6. Dilcia Fernandez
7. Lic. José Luis Caballero-- ASITENCIA SOLICITADA POR ALCADE
8. Ing. German Henríquez-- ASITENCIA SOLICITADA POR ALCADE

CHOLOMA MUNICIPALITY 669-3322/6693223

1. Lic. Armando Gale (Alcalde Municipal) (no)
2. Ing. Osman Alvarenga (Director de Servicios Públicos)
3. Ing. Julio César Hernández (Jefe de Servicios Públicos)
4. Ing. Edy Martínez (Asistente de Ingeniería)
5. Juan Ramón Mejía
6. Dario Perdomo

LIMON DE LA CERCA 882-5079/ 882-5011

1. Actilio Alvarez (Técnico DIMUSED)
2. Manuel Mejía (Técnico DIMUSED) (no)
3. Juan Benito Guevara (Alcalde Municipal) (no)

FUNDEMUN

1. Ing. Mario Alberto Garcia
2. Ing. Jenny Chávez (Choloma, Villanueva) 984-1577
3. Ing. Jose Tulio Gómez (La Lima) 647-3136

COE

1. Rueben Rosales

UTILA MUNINICIPALITY 425-3255

1. Monterrey Cárdenas (Alcalde Municipal)

UNITEC

11 de Julio 2001
Invitee List (Continued)

<u>AGUAS DE SAN PEDRO</u>
1. Ing. Claudia Enamorado

<u>SANAA</u>
1. Rodolfo Ochoa (Arturo Trochez en representación) (220-6506)

<u>USAID (236-9320)</u>
1. Carlos Verdial
2. Mauricio Cruz
3. Frank Almaguer (Embajador)
4. John Jones (Consul)
5. Timothy M. Mahoney (Director de la Misión)
6. Glenn Berce-Oroz (Director Interino de la oficna de Desarrollo Municipal e Iniciativa Democrática)
7. Charles Oberbeck

<u>PRIMHOR (239-4114)</u>
1. Alicia Villar Landa (Ing. Victor Manuel Leva Coordinador unidad SPS)

<u>USGS (236-7776</u>
1. John Walkey
2. Olman O. Rivera
3. Jeff Phillips

<u>FHIS</u>
1. Jorge Flores (992-6334)
2. Antonio Morales (980-2090)
3. Gunther Von-Weise
4. Ing. Samuel Alvarado

<u>USAGE</u>
1. Carlos Selva

<u>CHF</u>
1. Lourdes Retes (Asistirá *Nohemy Carrasco* de parte de HOGAR)
2. Lisa Pacholek (no asistirá)

Resend 6- 6-02; 6:28PM;Brown and Caldwell SACRAMENTO ;925 210 2487 # 12/ 17

LISTA ASISTENTES

11 de Julio 2001

HOTEL PRINCESS, SAN PEDRO SULA

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LISTA ASISTENTES

11 de Julio 2001

HOTEL PRINCESS, SAN PEDRO SULA

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[illegible] Saravia	Municipalidad Lima	Jefe. Serv. Pub.	668-24.00	668-26-01		
Julio César Hernández	Municipalidad Choloma	Asesor Tecnico	669-32-23	669-17-74	—	
[illegible] M. Leva	PRIMHUR	Gerente Regional	552-4590	554-40-04		
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TRAINING SESSIONS

GROUNDWATER MONITORING STUDIES/HONDURAS
GROUNDWATER MONITORING TRAINING
December 4, 6, and 10, 2001

INTRODUCTION

Brown and Caldwell performed three groundwater monitoring training events in early December, 2001, covering the five project municipalities. Similar training was conducted throughout Phase II of the project and the purpose of the recent training was to reinforce knowledge and practices learned by the participants during earlier fieldwork and training. Attached is the outline that was presented for the training session.

The training of Honduran personnel is essential to one of the project's main goals: project sustainability. The purpose of the training program is to ensure that each municipality will continue the Groundwater Level and Monitoring Program after the current project is completed.

These training sessions were conducted by Dean Wolcott, P.G., with the assistance of Barbara Goodrich and Fabiola Andrade (Sula Valley and Utila). Mr. Atilio Alvarez, technician for the municipality of Choluteca, assisted the BC staff in the Limon de la Cerca/Choluteca training session.

TRAINING PARTICIPANTS

The following lists describe the individuals who participated in the groundwater monitoring training. While the majority of participants are municipal engineers and technicians, personnel from non-governmental organizations were also invited and participated.

Site: Limon de la Cerca / Choluteca
Conducted by: Dean Wolcott, P.G., and Atilio Alvarez
Training date: December 4, 2001

PARTICIPANT	ORGANIZATION
Romulo Vivas	DIMUSEB/Choluteca
Guillermo Ordonez	DIMUSEB/Choluteca
Atilio B. Alvarez	DIMUSEB/Choluteca
Rosa Fiallos	PNUD/DIMUSEB
Cesar H. Mondragon	FUNDEMUN
Jorge Flores	FHIS

Site: La Lima, Villanueva, and Choloma
Conducted by: Dean Wolcott, P.G., Barbara Goodrich, and Fabiola Andrade
Training date: December 6, 2001

PARTICIPANT	ORGANIZATION
Jorge Nery Lopez Vasquez	La Lima Municipality
Jose Ruben Saravia	La Lima Municipality
Doris Marlenee Perez Lazo	La Lima Municipality
Alexis Orellana Martinez	La Lima Municipality
Jenny Mariela Chavez	FUNDEMUN
Jose Rigobero Rivera	Villanueva Municipality
Julio Cesar Hernandez	Choloma Municipality
Osman O. Alvarenga. M.	Choloma Municipality
Carlos R. Castillo L.	Choloma Municipality
Jose Francisco Casco P.	Villanueva Municipality
Hector A. Cabrera	Villanueva Municipality
Olga Lara de Hubin	Choloma Municipality
Antonio Morales Flores	FHIS

Site: Island of Utila
Conducted by: Dean Wolcott, P.G., Barbara Goodrich, and Fabiola Andrade
Training Date: December 10, 2001

PARTICIPANT	ORGANIZATION
Jonell Jackson	
Joslyn J. Ponce	
Alton Cooper	Utila (Mayor Elect)
Glenn Gabourel	Island Spring
Jorge Flores	FHIS
Gilda Ordonez	Utila
Carolina Escobar	Utila

TRAINING TOPICS

The subject matter of the training sessions consisted of all relevant technical material associated with the Groundwater Level and Monitoring Program. Topics included monitoring system well selection criteria, groundwater level measuring methodology, groundwater sampling methodology, field analysis of groundwater samples, laboratory analysis of groundwater samples, quality assurance/quality control, and data interpretation.

Each training session consisted of a classroom lecture and discussion followed by a hands-on field practice session where monitoring and data collection activities were conducted at a monitoring well.

A special emphasis was placed on proper documentation of field activities and the use of designated data collection forms developed for the Program.

TRAINING MATERIALS

Training participants were provided with a copy of the Groundwater Level and Monitoring Program Field Manual. This field manual contains detailed descriptions of the activities contained in the monitoring program, copies of field data forms, pictures of specific field activities, and a list of wells in the monitoring well network for each municipality.

Materials provided in the training sessions included an electronic water level meter, Oakton field water quality kit, groundwater sample kit, water filter apparatus, and other monitoring equipment.

Water Resources Management System
Training Summary
February 12 and 14, 2002

Introduction

Brown and Caldwell conducted two training workshops in February to train representatives from each municipality on the use of the Water Resources Management System (WRMS). The WRMS is a custom database and geographic information system application that has been custom developed to use as a water resource planning tool to support the goals of this project.

Integration of the use of the WRMS with the other recommendations and programs established in this project are essential to the main project goal of providing for sustainable water resource management in the future. The WRMS has been designed to support other project programs such as the Groundwater Level and Monitoring Program (training conducted in December, 2001). The purpose of this training was to provide hands-on training and experience with the WRMS application so that the municipalities can use it to maintain and manage data and to use the tool for future decision-making.

The main goals of the training were to gain an understanding of the capabilities of the WRMS, learn how to enter and manage data, and create maps and reports from data in the database. Each workshop consisted of a one-day hands-on course and covered a system overview, how to start using the system, entering infrastructure data, accessing other resources, system administration, creating GIS basemaps, and using well prioritization tools. The following workshops were conducted:

- UNITEC Campus, San Pedro Sula, February 12, 2002;
- UNITEC Campus, Tegucigalpa, February 14, 2002.

Training Topics

Each workshop was conducted at the UNITEC computer laboratory and each participant had their own computer and a training copy of the database. The participants used a 114 page training manual that contained a detailed discussion of each function in the WRMS, theory and recommendations for best practices, and 20 individual exercises designed to provide hands-on training and practice. During the training, the following objectives were successfully accomplished by the participants:

- Learn the components of the WRMS
- Enter and edit service areas data
- Enter well information
- Store images and other electronic files
- Enter water quality samples and water levels
- Enter storage tank information
- Create reports from the database

- Learn how to access other resources (the USGS Groundwater Well Database, Municipal Water Resources Reports, etc.)
- View wells and storage tanks on a map
- Use the basic functionality of ArcView to create a map
- Display well information on a map (water level, water quality, depth, etc.)
- Overview of the well site prioritization tool

Training Participants

Training was conducted by Allan Scott of Brown and Caldwell, with assistance from Fanny Letona (ATICA), David Esponiza (ATICA), and Fabiola Andrade (Brown and Caldwell).

The following are lists of the individuals that participated in the workshops.

San Pedro Sula, February 12, 2002 participants:

Participant	Organization
Ramón Jimenéz Florez	Villanueva Municipality
José Rigobero Rivera	Villanueva Municipality
Francisco Casco	Villanueva Municipality
Marvin Pinador	Villanueva Municipality
Jackeline Reyes	La Lima Municipality
Jose Ruben Saravia	La Lima Municipality
Carlos H. Ochoa	La Lima Municipality
Doris Perez	La Lima Municipality
Julio Cesar Hernández	Choloma Municipality
Ruglio Diaz	UNITEC

Tegucigalpa, February 14, 2002 participants:

Participant	Organization
Mauricio Cruz	USAID
Carlos Verdial	USAID
Jorge Flores	FHIS
Glenn Gabourel	Utila Municipality
John Walkey	USGS

PROJECT WRAP-UP MEETINGS

USAID Groundwater Water Resources Management Project
Project Wrap-up Workshop Agenda

Introductions (All)

Project Purpose (USAID)
- History
- Objectives

Project Sequence (BC/Atica)
- Initial data gathering
- Conceptual model development
- Field Investigation
- Groundwater flow model
- Evaluation

Results and Findings (BC/Atica)
- Water requirements/demand
- Aquifer characteristics
- Groundwater quality
- Future wells
- Well head protection

Data base (BC/Atica)

Training (BC/Atica)

Computers & Equipment (USAID)

Recommendations/Summary

Break

Field visit to wells